rli

THE HUNTING TOWER AT CHATSWORTH.

THE

RUDIMENTS OF ARCHITECTURE

AND BUILDING,

FOR THE USE OF

ARCHITECTS, BUILDERS, DRAUGHTSMEN, MACHINISTS, ENGINEERS, AND MECHANICS.

EDITED BY JOHN BULLOCK,
AUTHOR OF "THE AMERICAN COTTAGE BUILDER."

NEW EDITION, REVISED.

NEW YORK.
STRINGER & TOWNSEND,
222 BROADWAY.
1855.

R. CRAIGHEAD, PRINTER AND STEREOTYPER,
53 VESEY STREET, N. Y.

HISTORY

AND

RUDIMENTS OF ARCHITECTURE.

PREFACE TO REVISED EDITION.

This book originally appeared in two volumes, "The History and Rudiments of Architecture," and "Rudiments of the Art of Building." Whatever errors they may have contained have been corrected in this "Revised Edition," and much new matter and many new engravings have been added. The book is now uniform with "The American Cottage Builder."

We have dealt freely with our authors—correcting where they mistook—extending where we thought they were not clear—curtailing where we imagined they were too profuse in their remarks—and rejecting those illustrations and allusions which possess no interest to the American reader.

In the various departments, we have made free use of Weale's Series, copying from it such information as seemed appropriate and valuable, sometimes using the very words, and at others simply condensing its information.

It was not without much hesitation that we retained the algebraic signs made use of in the book, especially in Section I.; but those readers who do not understand them may safely omit them without losing the substance of the work, while those to whom they are familiar will find them valuable.

It must not be forgotten that the book on Architecture is a "Rudimentary" Treatise, and all that it promises is to introduce the reader into the porch of the temple of Artistic Science, doubting not that he will be so pleased and instructed that he will go in the Temple, even to the *sanctum sanctorum*—the holy of holies.

The book on Building is edited from Dobson, and is intended as a "First Book on the Art of Building, designed for the use of young persons who are about to commence their professional training for any pursuit connected with the erection of Buildings; and also for the use of amateurs who wish to obtain a general knowledge of the subject without devoting to it the time requisite for the study of the larger works that have been written on the different branches of construction."

JOHN BULLOCK, *Editor.*

CONTENTS.

HISTORY

AND

RUDIMENTS OF ARCHITECTURE.

BOOK I.

THE ORDERS.

In its architectural meaning, the term ORDER refers to the system of columniation practised by the Greeks and Romans, and is employed to denote the columns and entablature together; in other words, both the upright supporting pillars and the horizontal beams and roof, or *trabeation*, supported by them. These two divisions, combined, constitute an Order; and so far all Orders are alike, and might accordingly be reduced to a single one, although for convenience they are divided into *five* leading classes or families, distinguished as the DORIC, TUSCAN, IONIC, CORINTHIAN, and COMPOSITE.

It would be a mistake to suppose that inasmuch as the Orders are divided into five classes, there is for each of them one fixed, uniform character; for such a belief has led to a mechanical treatment of the respective Orders themselves, nothing being left for the Architect to do, so far as the Order which he employs is concerned, but merely to follow the example which he has selected; in other words, merely to *copy*, instead of *designing*.

Each leading class is distinct from the others, yet comprises many varieties or *species*, which, however much they may differ with respect to minor considerations, all evi-

dently belong to one and the same style, which we call Order. We have now to consider their constituent parts, that is, those which apply to every order alike. Hitherto it has been usual with most writers, to treat of an Order as consisting of three principal parts or divisions, *viz.*, pedestal, column, and entablature. The first of these, however, cannot by any means be regarded as an integral part of an Order. So far from being an essential, it is only an *accidental* one,—one, moreover, of Roman invention, and applicable only under particular circumstances. The pedestal no more belongs to an Order than an attic or *podium* placed above the entablature. In the idea of an Order we do not include what is extraneous to the Order itself; it makes no difference whether the columns stand immediately upon the ground or floor, or are raised above it. They almost invariably are so raised, because, were the columns to stand immediately upon the ground or a mere pavement, the effect would be comparatively mean and unsatisfactory; the edifice would hardly seem to stand firmly, and, for want of apparent footing, would look as if it had sunk in the ground, or the soil had accumulated around it. With the view, therefore, of increasing height for the whole structure, and otherwise enhancing its effect, the Greeks placed their temples upon a bold substructure, composed of *gradini*, or deep steps, or upon some sort of continuous *stylobate;* either of which modes is altogether different from, and affords no *precedent* for, the pedestal of modern writers. Essential as some form of *stylobate* is to the edifice itself, it does not properly belong to it, any more than that equally essential—in fact, more indispensable part—the roof.

The pedestal being discarded as something apart from the Order itself, the latter is reduced to the two grand divisions of COLUMN and ENTABLATURE, each of which is subdivided into three distinct parts or members, viz., the COLUMN, into *base, shaft,* and *capital;* the ENTABLATURE, into *architrave, frieze,* and *cornice;* so that the latter is to the entablature

what the capital is to the column, namely, its crowning member—that which completes it to the eye. Yet, although the above divisions of column and entablature hold good with regard to the general idea of an order, the primitive Greek or Doric one does not answer to what has just been said, inasmuch as it has no base—that is, no mouldings which distinctly mark the foot of the column as a separate and ornamented member. Hence, it will, perhaps, be thought that this Order is not so complete as the others, since it wants that member below which corresponds with the capital above. Still, the Grecian Doric is complete in itself—it needs no base: in fact, does not admit of such addition, without forfeiting much of its present character, and thus becoming something different. Were there a distinct base, the mouldings composing it could not very well exceed what is now the lower diameter or actual foot of the column; because, were it to do so, either the base would become too bulky, in proportion to the capital, or the latter must be increased, so as to make it correspond in size with the enlarged lower extremity. Even then, that closeness of *intercolumniation*(spacing of columns) which contributes so much to the majestic solidity that characterizes the genuine Doric, could not be observed: unless the columns were put considerably further apart, the bases would scarcely allow sufficient passage between them. The only way of escaping from these objections and difficulties, is by making the shaft of the column considerably more slender; so that what was before the measure of the lower diameter of the shaft itself, becomes that of the base. That can be done—has been done—at least something like it; but the result is an attenuated Roman or Italian Doric, differing altogether in proportions from the original type, or order. The shaft no longer tapers visibly upwards, or, what is the same thing, expands below.

Before we come to speak of the orders severally and more in detail, there are some matters which require to be noticed; one of which is the origin of the Greek system of columnation,

or the prototype upon which it was modelled. Following Vitruvius, nearly all writers have agreed to recognize in the columnar style of the ancients the primitive timber hut, as furnishing the first hints for, and rudiments of, it. Such theory, it must be admitted, is sufficiently plausible, if only because it can account very cleverly for many minor circumstances. Unfortunately, it does not account at all for, or rather is in strong contradiction to, the character of the earliest extant monuments of Greek architecture. Timber construction would have led to very different proportions, and different tastes. Had the prototype or model been of that material, slenderness and lightness, rather than ponderosity and solidity, would have been aimed at; and the progressive changes in the character of the Orders would have been reversed, since the earliest of them all would also have been the lightest of them all. The principles of stone construction have so evidently dictated and determined the forms and proportions of the original Doric style, as to render the idea of its being fashioned upon a model in the other material little better than an absurd, though time-honored fiction. Infinitely more probable is it, that the Greeks derived their system of architecture from the Egyptians; because, much as it differs from that of the latter people with regard to taste and matters of ornamentation, it partakes very largely of the same *constitutional* character. At any rate, the doctrine of the timber origin applies as well to the Egyptian as to the Hellenic or Grecian style. Indeed, if there be anything at all that favors such doctrine, it is, that construction with blocks of stone would naturally have suggested square pillars, instead of round ones; the latter requiring much greater labor and skill to prepare them than the others. But, as their pyramids and obelisks sufficiently testify, the most prodigal expenditure of labor was not at all regarded by the Egyptians. That, it will perhaps be said, does not account for the adoption of the circular or cylindrical form for columns. We have therefore to look for some sufficiently

probable motive for the adoption of that form; and we think we find it in convenience. In order to afford due support to the massive blocks of stones placed upon them, the columns were not only very bulky in proportion to their length, but were placed so closely together, not only in the fronts of porticos, but also within them, that they would scarcely have left any open space. Such inconvenience was accordingly remedied by making the pillars round instead of square. Should such conjectural reason for the adoption of circular columns be rejected, it is left to others to propound a more satisfactory one, or to abide, as many probably will do, by the old notion of columns being so shaped in order to imitate the stems of trees. It is enough that whatever accounts for the columns being round in Egyptian architecture, accounts also for their being the same in that of the Greeks.

Among other fanciful notions entertained with regard to columns and their proportions, is that of the different orders of columns being proportioned in accordance with the human figure. Thus the Doric is said to represent a robust male figure, and those of the Ionic and Corinthian, female ones, —the Ionic, a matron; the Corinthian, a less portly specimen of feminality. Now, so far from there being any general similitude between a Grecian Doric column and a robust man, their proportions are directly opposite,—the greater diameter of the column being at its foot, while that of the man is at his shoulders. The one tapers *upwards*, the other *downwards*. If the human figure and its proportions had been considered, columns would, in conformity with such type, have been wider at the top of their shafts than below, and would have assumed the shape of a terminus of a mummy chest. With regard to the other orders mentioned, it is sufficient to observe, that if so borrowed at all, the idea must have been preposterous. We happen to have a well known example of statues or human figures, and those, moreover, female ones, being substituted for columns beneath an

entablature; and so far are they from confirming the pretended analogy between the Ionic column and the proportions of a female, that they decidedly contradict it, those figures being greatly bulkier in their general mass than the bulkiest and stoutest columns of the Doric Order. At any rate, one hypothesis might satisfy those who will not be satisfied without some fancy of the kind, because two together do not agree; if columns originated in the imitation of stems of trees, we can dispense with the imitation of men and women, and *vice versa*.

Some may think it scarcely worth while to notice such fancies, yet they are a part of architecture as generally taught and usually understood, at least, in this country.

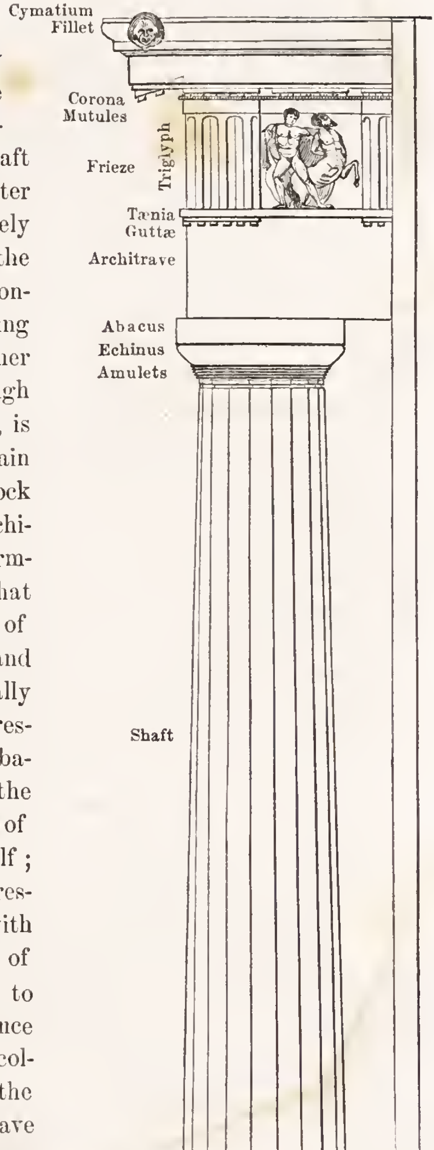
We do not pretend to explain and trace, step by step, the progress of the Doric Order, and of the column or system of the Greeks, from their first rudiments and formation. We have only the results of such progressive formation or develepement; of the actual formation itself we neither know nor can we know anything. The utmost that can now be done is to take the results themselves, and from them reason backwards to causes and motives. Adopting such a course, we may first observe, that there is a very striking and characteristic difference between Egyptian and Grecian taste and practice in one respect: in the former style the columns are invariably *cylindrical*, or nearly so,—in the other they are *conical*, that is, taper upwards, and in some instances so much so, that were they prolonged to double their height, they would be almost perfect cones, and terminate like a spire. This tapering greatly exceeds that of the stems of trees, taking from their stem the trunk, from above which the branches begin to shoot out. It appears to have been adopted for purely artistic reasons, certainly not for the sake of any positive advantage, since the diminution of the shaft, and the great contraction of the diameter just below the capital, must rather decrease than at all add to the strength of the column.

What then are the artistic qualities so obtained? We reply,—variety and contrast and the expression of strength without offensive heaviness. The sudden or very perceptible diminution of the shaft,—it must be borne in mind that our remarks refer exclusively to the original Greek Style or Doric Order,—produces a double effect; it gives the column an expression of greater stability than it otherwise would, combined with comparative lightness. What is *diminution* upwards, is *expansion* downwards; and similar difference and contrast take place with respect to the intercolumns, although in a reverse manner, such intercolumns being wider at top than at bottom. So far the principle of contrast here may be said to be two-fold, although one of the two sorts of contrast inevitably results from the other. Were it not for the great diminution of the shaft, the columns would appear to be too closely put together, and the intercolumns much too narrow—that is, according at least, to the mode of intercolumniation practised by the Greeks in most of their structures in the Doric Style; whereas such offensive appearance was avoided by the shaft being made considerably smaller at the top than at the bottom,—consequently the intercolumns wider above than below, in the same ratio; so that columns which at their bases were little more than one diameter apart, became more than two—that is, two upper diameters apart at the top of their shafts, or the neckings of their capitals. In this style everything was calculated to produce a character of majestic simplicity,—varying, however, or rather progressing, from heaviness and stern severity to comparative lightness of proportions,—for examples differ greatly in this respect: in some of the earlier ones the columns are not more than four diameters in height, while in some of the later they are upwards of six, which last mentioned proportions not only amount to slenderness, but also destroy others. The capital itself may be proportioned the same as before relatively to the diameter of the column, but it cannot possibly bear the same ratio as before to its height

The average proportions for that member are one diameter for its width at its abacus, and half a diameter for its depth ; consequently, if the entire column be only four diameters in height, the capital is one-eighth of it, or equal to one-seventh of the shaft ; whereas, if the column be six or more diameters, the capital becomes only one-twelfth of the column, or even less, so that the latter appears thin and attenuated, and the other member too small and insignificant. Yet though the original Greek Order or style exhibits considerable diversity with respect to mere proportions, it was otherwise very limited in its powers of expression, and moreover something quite distinct from the nominal Doric of the Romans and Italians, as will be evident when we compare the latter with it

Before we enter upon this part of our subject, and previous to an examination of the details of the several orders, it should be observed that the diameter, that is the *lower* diameter of the column, is the standard by which all the other parts and members of an order are measured. The diameter is divided into 60 *minutes*, or into two halves or *modules* of 30 minutes each ; and those minutes are again subdivided into parts or *seconds* when extreme accuracy of measurement is required ; which two last are noticed : 4′. 10», for instance, meaning four minutes and ten seconds.

DORIC ORDER.



It has been already observed, that in the genuine Doric the column consists of one shaft and capital, which latter is composed of merely an *echinus* and *abacus*, the first being a circular convex moulding, spreading out beneath the other member, which, although a very important one, is no more than a plain and shallow square block upon which the architrave rests, not only firmly and safely, but so that the utmost expression of security is obtained, and pronounced emphatically to the eye. Such expression arises from the abacus being larger than the *soffit*, or under surface of the architrave itself; and as the former corresponds, or nearly so, with the lower diameter of the shaft, it serves to make evident at a glance that the foot of the column is greater than the soffit of the architrave placed upon the columns.

Thus, as measured at either extremity, the column is

greater than the depth or thickness of the architrave, and projects beyond the architrave and general plane of the entablatuure. Now this would produce a most unsightly effect were the columns of the same or nearly the same diameter throughout. In such case they would appear not only too large, but most clumsily so, and the entablature would have the look of being set back in the most awkward and most unaccountable manner. Instead of which, the architrave, and consequently the general plane of the whole entablature, actually overhangs the upper part of the whole shaft, in a plane about midway between the smallest diameter of the column, just below the capital and the face of the abacus. Even this, the overhanging of the entablature, would be not a little offensive to the eye, were the abacus no larger than the architrave is deep; whereas, being larger, it projects forward farther than the face of the architrave, thereby producing a powerful degree of one species of artistic effect, namely, contrast,—and if contrast, of variety also; for though there may be variety without contrast, there cannot be contrast without variety. Another circumstance to be considered is, that were not such projection beyond the face of the architrave given to the abacus, that and the rest of the capital could not correspond with the foot of the shaft, and thus equalize the two extremities of the entire column. As now managed, all contradictions are reconciled, and the different sorts of contrast are made to contribute to and greatly enhance general harmony. In the outline of the column we perceive, first contraction,—then expansion, and that in both directions,—for in like manner as the column diminishes upwards and the capital expands from it, its shaft may be said to expand and increase in bulk downwards, so as to agree with the abacus or upper extremity.

The Doric column was generally *fluted*—that is, cut into a series of ridges upon its surfaces. The generally-received theory is, that this fluting represents cracks or crevices in the stems of trees, or from the streaking of rain on the shafts

of columns. It is unnecessary to discuss the truth or falsity of that theory. It is sufficient that there are good artistic reasons why it should be so: with the same, or very nearly the same solidity as before, it causes the columns to appear much less heavy than it otherwise would do, and contributes to a pleasing diversity of light and shade. Being upon a curved surface, the channels serve to render the circularity of the columns more apparent, since, though they are all of the same width, they show narrower and narrower to the eye on each side of the centre one, no matter in what direction the column is viewed. Here, then, we have variety, combined with uniformity, and a certain apparent or optical irregularity, with what we know to be perfect regularity.

In the Doric Order the number of channels is either sixteen or twenty, afterwards increased in the other Orders to twenty-four, for they are invariably of an even number, capable of being divided by four, so that there shall always be a centre flute on each side of the column, that is, in a line with the middle of each side of the abacus. Doric flutings are much broader and shallower than those of the other Orders. The mode of fluting Doric columns with mere *arrises* between the channels, instead of *fillets*, has been retained by the moderns, as characteristic of the order. On the original Doric, almost every part is marked by breadth, or by flatness, or by sharpness. There are no curved mouldings or surfaces, except the *cymatium* of the cornice or the *echinus* of the capital, which last is generally kept exceedingly flat. All of the parts are in perfect keeping with the style. The horizontal, annular, narrow channels, or incisions beneath the *echinus* of the capital, are probably merely for the sake of effect—of producing shadow, and increasing the proportions of the capital, to which they seem to belong. The lowermost groove may give the capital the appearance of being a separate piece, merely joined on to the shaft, without such joining being concealed. It marks the commencement of the capital, the portion above it of the shaft being thereby converted into the *hypotrachelium*

or necking of the capital itself, which is thus enlarged in appearance, without having actually increased, and rendered unduly heavy. In some examples of the order, this groove is a mere line, and in others it is omitted altogether. The office of the *echinus*, by expanding out, to connect the diminished upper end of the column with the overhanging abacus, and the former being circular, and the latter square, but adapted to each other in size, a beautiful combination is produced of a circle inscribed within a square; and the result is variety, contrast, and harmony. In its profile, or *section*, by which latter term is understood the contour of any moulding, or other member, it is usually very flat—little more than a portion of a cone (turned downwards), with scarcely any perceptible degree of convexity, except just beneath the abacus, where it is suddenly rounded and diminished, so that the abacus does not seem to press upon or compress it too much.

The *epistylium*, or architrave, is the first or lowest division of the entablature. It is no more than a plain surface, whose standard height, including the *tænia*, or fillet, which finishes it, and separates it from the frieze, is equal to the upper diameter of the column. The middle division of the entablature is the frieze, which is a very characteristic feature of this Order, being invariably distinguished by its tryglyphs and metopes. The triglyphs are upright channelled blocks, affixed to, or projecting from, the frieze, and are supposed to have been originally intended to represent the ends of inner beams, laid upon the architrave transversely. The metopes, on the contrary, are not architectural members, but merely the intervals or spaces between the triglyphs; so that, without the latter, there could not be the others, because it is triglyphs which produce the metopes. With slight variations in different examples, the frieze is about the same height as the architrave—a trifle less, rather than more; and the average proportion for the breadth of the triglyphs is the mean diameter of the column, or that taken midway of the shaft. The face of the triglyph has two glyphs, or

channels, carved upon it, and its edges beveled off into a half channel, thus making what is equal to a third glyph—whence the name triglyph, or *three-channelled.* The fillet and guttæ attached to the tænia of the architrave immediately beneath each triglyph, and corresponding with it in width, belongs to the triglyph, although it shows itself upon the architrave. These small conical guttæ, or *drops*, are supposed by some to represent drops of rain that have trickled down the channels of the triglyph, and settled beneath the ledge of the architrave. Others suppose them to have been intended to indicate the heads of nails, screws, or studs. The artistic intention would seem to be to impart somewhat of decoration to the architrave, to break the monotony of the otherwise uninterrupted line of the tænia, and to connect to the eye, at least, the architrave and fricze together. The architrave thus exhibits, in a fainter degree, the same system of placing ornamental members at regular distances from each other, as is so energetically pronounced in the frieze itself.

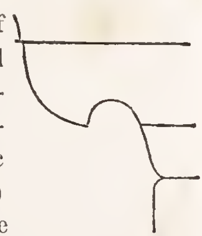
One triglyph is placed over every column, and one or more intermediately over every inter-column (or space between two columns), at such distance from each other, that the metopes are square; in other words, the height of the triglyph is the measure for the distance between it and the next one. In the best Greek examples of the Order, there is only a single triglyph over each inter-column, which is the closest of all, the distance from axis to axis of the columns being limited to the space occupied above by two metopes and two triglyphs, *i. e.*, one whole tryglyph and two halves of triglyphs. The width of the inter-columns cannot be at all less than the proportion above mentioned; neither can it be increased without a second tryglyph—and if a second triglyph, a second metope also, over each inter-column, thus augmenting the distance between the columns half as much again, which becomes, perhaps too much, the difference between that and the other modes, being considerably more

than the diameter of the column; whereas, in the other Orders, the inter-columns may be made, at pleasure, either a little wider or narrower than usual. The end triglyphs of the Grecian Doric are placed quite up to the edge, or outer angle of the frieze.

The Doric CORNICE is the last division of the entablature. It is about a third or even more than a third less than the others, and may itself be divided into three principal parts or members, viz., the *corona*, with the mutules and other *bed mouldings* beneath it, and the *epitithetas* above it. The mutales are thin plates or shallow blocks attached to the under side or soffit of the corona, over each triglyph and each metope, with the former of which they correspond in breadth, and their soffits or under-surfaces are wrought with three rows of *guttae* or drops, conical or otherwise shaped, each row consisting of six *guttae*, or the same number as those beneath each triglyph. Nothing can be more artistically disposed; in like manner, as an intermediate triglyph is placed over every two columns, so is an intermediate mutale over every two triglyphs. The smaller members increase in number as they decrease in size; and in the upper and finishing part of the Order, the eye is led on horizontally, instead of being confined vertically to the lines indicated by the columns below. The corona is merely a boldly projecting flat member, not greatly exceeding in its depth the abacus of the capital; and in some examples it is even less. The epitithetas, or uppermost member of the cornice, is sometimes a cymatium, or *wavy* mouldering, convex below and concave above; sometimes an echinus mouldering, similar in profile to the echinus of the capital. The cornice may be said to be to the entablature, and indeed to the whole Order, what the capital is to the column,—completing and concluding it in a very artistic manner. By its projection and the shadow which it casts, the cornice gives great spirit and relief to the entablature, which would else appear both heavy and unfinished. In the horizontal cornice beneath a pediment, the

epitithetas is omitted, and shows itself only in the sloping, or racking cornices, as they are called, along the sides of the pediment.

Antæ.—Pilasters, as well as columns, belong to an Order, and in modern practice are frequently substituted indifferently for columns, where the latter would be *engaged* or attached to a wall. In Grecian architecture, however, the *antæ*,—as they are thus termed, to distinguish them from other pilasters,—are never employed. They are never placed consecutively, or in any series, but merely as a facing at the end of a projecting wall, as where a portico is enclosed at each end by the walls forming the sides of the structure, in which case it is described as a portico *in antis*. Although they accompany columns, and in the case just mentioned, range in the same line with them, antæ differ from them inasmuch as their shafts are not diminished; for which reason their faces are not made so wide as the diameter of the columns, neither are their capitals treated in the same manner, and both shaft and capital would be exceedingly clumsy. The expanding echinus of the column capital is therefore suppressed, and one or more very slightly projecting *faciæ*, the uppermost of which is frequently hollowed out below, so as to form in section what is called the "bird's nest" moulding. In a portico *in antis* the want of greater congruity between the antæ and the columns is made up for by various contrasts. Flatness of surface is opposed to rotundity, vertical lines to inclined ones (those of the outline and flutings, of the column) and uniformity, in regard to light, to the mingled play of light and shade on the shafts of the columns



The Greeks never channelled the faces of their *antæ*, whereas the moderns flute their pilasters as well as columns. The artistic reason for such a distinction would seem to have been to prevent harshnesss and dryness of effect—all the lines being parallel to each other, while in the columns all

the lines approach each other towards the top and would meet if the column were extended far enough.

PEDIMENT.—The pediment may properly be considered as no part of the Order, but it serves to illustrate how a figure which, considered merely in itself, is generally regarded as neither beautiful nor applicable to architectural purposes, may be rendered eminently beautiful and satisfactory to the eye. The pediment must, when it does appear, be in accordance with the order itself, or that front of the building which is beneath the pediment ; consequently the pitch of the latter must be regarded by circumstances,—must be either greater or less according to the proportions of the front itself. So far from being increased in the same ratio, the wider the front,—the greater the number of columns at the end of the building,—the lower must the pediment be kept, because the front itself becomes of *low proportions* in the same degree as it is extended or widened. Under all circumstances, the height of the pediment must remain pretty nearly the same, and be determined, not by width or horizontal extent, but by the height of what is beneath it. The height of the pediment or its *tympanum* (the triangular surface included between the horizontal cornice of the Order, and the two racking cornices of the pediment) never greatly exceeds the depth or height of the entablature ; for were it to do so, the pediment would become too large and heavy, would take off from the importance of the Order, and appear to load its entablature with an extraneous mass which it was never calculated to bear. It was a very usual practice among the ancients to fill the whole of the tympanum of the pediment with sculpture, and also the metopes of the frieze, by which the latter instead of being mere blank spaces between the triglyphs, were converted into ornamental features.

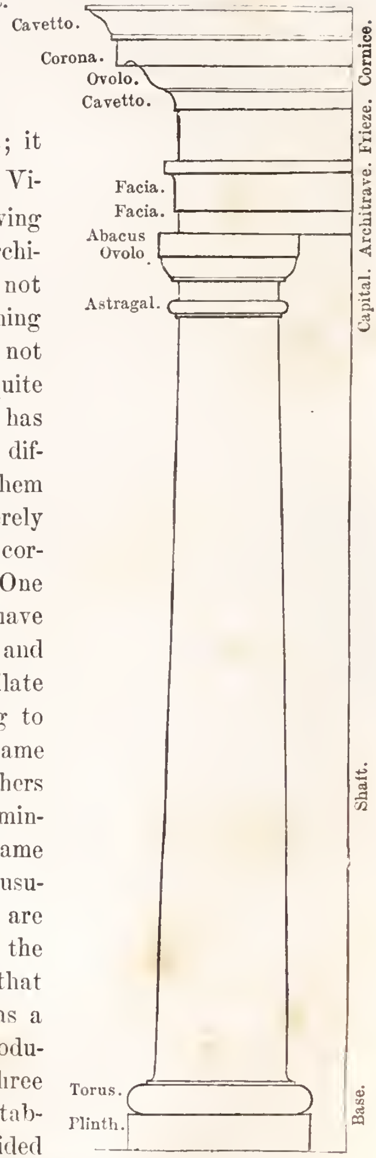
MODERN DORIC.

The Modern Doric resembles the original one in the mode of fluting the *arrises* instead of fillet—the general form of

capital composed of echinus and abacus, and the triglyphs upon the frieze. The differences are: the column is increased from six to eight diameters. The sunk annulets beneath the capital were omitted or converted into fillets; the capital was increased in depth by a distinct necking being given to it, divided from the shaft by a projecting moulding, which in that situation is called an *astragal.* The greatest change is the addition of a base to the column. The base best adapted to the Order, as being the most simple, though not uniformly made use of, is that which consists merely of a *torus,* or large circular and convex-sided block, and two shallow fillets above it. It may here further be noticed, that beside the base itself, or the base *proper*, the moderns have, for all the Orders alike, adapted an additional member, namely, a rather deep and square block, which, when so applied, is termed a *plinth;* and beneath this is frequently placed another and deeper one called a *sub-plinth.*

Though greatly altered, not to say corrupted, from its primitive character, the Doric Order, as treated by the moderns, has been assimilated to the other Orders,—so much so as, though still differing from them in details, to belong to the same general style. One advantage, if no other, of which is, that it may, should occasion require, be used along with the other Orders; whereas the original Doric is so obstinately inflexible that it cannot be made to combine with anything else, or to bend to modern purposes.

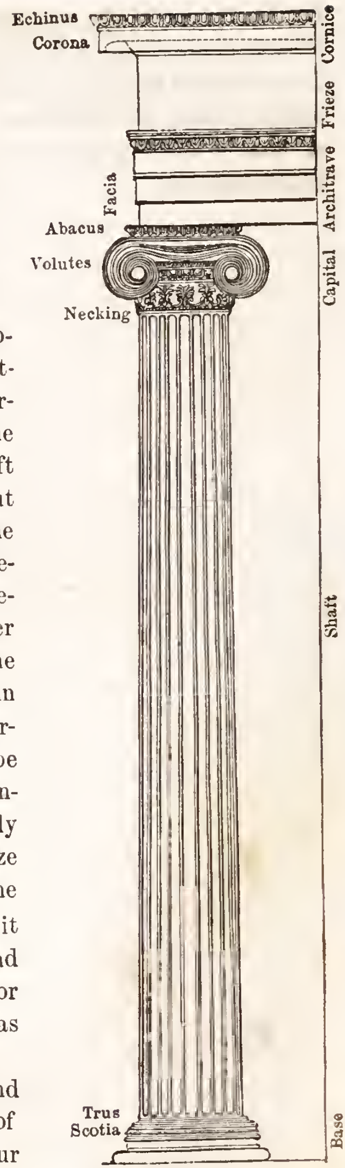
TUSCAN ORDER.



This Order is derived from the Doric. No authentic examples of it exist; it is known only from what Vitruvius says of it, following whose account, modern architects have endeavored, not fruitlessly, to make some thing out of it. The shafts are not fluted and the frieze is quite plain. The Tuscan Order has been differently treated by different Architects, some of them having given it what is merely a modification of the Doric cornice, without its mutales. One thing which the moderns have done, both in their Doric and their Tuscan, is to assimilate pilasters to columns, giving to the former precisely the same bases and capitals as the others have, and also generally diminishing their shafts in the same manner. The proportions usually adopted for this order are as follows:—the height of the column seven diameters; that is, considering the order as a kind of Doric, fourteen modules; and the entablature, three modules and a half. The entablature may then be divided into ten equal parts, three of which are to be appropriated

for the height of the architrave, three for the frieze, and the remaining four for the cornice. The capital of the column has the height of one module, and the base has the same; so that the height of the shaft, including the ring or fillet, which separates the shaft and capital, must be twelve modules.

IONIC ORDER.



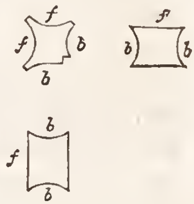
The capital is the indical mark of the Order,—that by which the eye immediately recognizes and distinguishes it. The entire column is of quite a different character from the Doric. Besides having the addition of a base, the shaft is of more slender or taller proportions, and consequently much less visibly tapering; for if it diminishes in the same degree as the Doric shaft does,—the Ionic being about two diameters longer,—the upper one would, in consequence of such tapering, become too small; and a further consequence would be that the foot and base of the column would appear too large,—perhaps clumsily so. It must be allowed that the swelling contours of the base are admirably in keeping, and harmonize with the play of curves in the volutes much better than it would were the shaft to stand immediately upon the floor or pavement without any base, as in the Doric Order.

Concerning the origin and progress of the development of this order to perfection, our present limits will not permit us to speak. The number of

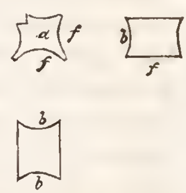
fillets is twenty-four. The Ionic capital is far more irregular and complex than that of the Doric.

Instead of showing, like the other, four equal sides, it exhibits two faces or fronts parallel to the architrave above it, and two narrower *baluster* sides, as they are termed, beneath the architrave. Some consider this irregularity a defect, which, if such it be, is to be got over only by either turning the volutes diagonally, as in some Roman and modern examples, or by curving concavely the faces of the capital, instead of making them planes, so as to obtain four equal faces or sides, as is done in the capitals of the inner Order of the Temple of Apollo at Bassae. At least that method and the other one of turning the volutes diagonally, are the only methods that have been practised for giving perfect regularity to the Ionic capital by means of four equal faces; for, though difficult, it is possible to accomplish the same purpose differently, by making the abacus quite square, as in the Doric Order, and letting the volutes grow out of it on each side or face, their curvature commencing not at the upper horizontal edge, but descending from the vertical edges of the abacus. The capitals could not be square without appearing of excessive bulk, and out of proportion with the other parts, and inconsistent with the delicacy aimed at in all respects. This arises from the great extent of the two flat voluted faces. It is objected against the Ionic capital that in the end columns of a portico the form occasioned obvious, if not offensive irregularity, because on the return side of the building the baluster side showed itself beneath the face of the architrave: yet even this was of little consequence if there was merely a single row of columns in front; but where the colonnade was continued along the flanks of the building also, a very unsightly sort of irregularity was produced; for while all the other columns on those flanks showed the faces of their capitals, the end one would show its baluster side. To obviate this objection the volute was placed at the angle, diagonally,

so as to obtain these two voluted surfaces placed immediately back to back. In the British Museum and some other modern edifices this objection is attempted to be obviated by arranging the corner volutes as shown in Figs. 4 and 5, in



which *f* indicates the face or voluted side of the capital, and *b* the baluster side. In an external angle, or the return of a portico, the faces and sides are arranged thus, so that *b b b b* come opposite each other; but in an internal or re-entering angle, the reverse takes place ; for we have then this disposition of the faces and sides of the capitals, in which a voluted face comes opposite to the baluster side of the next capital,—a most unsightly irregularity, and an



objection that would be far better got over by making the column [*a*] into a square pillar, which would besides give strength, or the expression of it, where such expression is very desirable. The capital sometimes has and sometimes has not a necking to it, which may be either plain or decorated. The capital is capable of infinite modifications in its proportion to the column, and as regards the size of the volutes compared with the width of the face. In the best Greek examples the volutes are much bolder and larger than in those of the Roman and Italian, in some of which they are so greatly reduced in size, and become consequently so far apart from each other, as to be insignificant in themselves, and give the whole capital an expression of meanness and meagreness. The *spirals* forming the volute supply another source of variety, since they may be either single or manifold. In what is called the Ilissus Ionic capital there is only a single spiral, or *hem*, whose revolutions form the volute, which mode, indeed, prevails in all the Roman and modern Ionics; but in the capitals of the Temple of Erecthus, at Athens, there are, besides that principal spiral, either intermediate

ones which follow the course of its revolutions. Again, the *cathetus*, or eye of the volute, where the spiral or spirals terminate, admits of being made smaller or larger. It is, besides, sometimes flat, sometimes convex, and occasionally carved as a *rosette.* All these variations are independent of the general composition of the capital, and though not all equally good, they both suggest and authorize other modifications of the Ionic type, and fresh combinations.

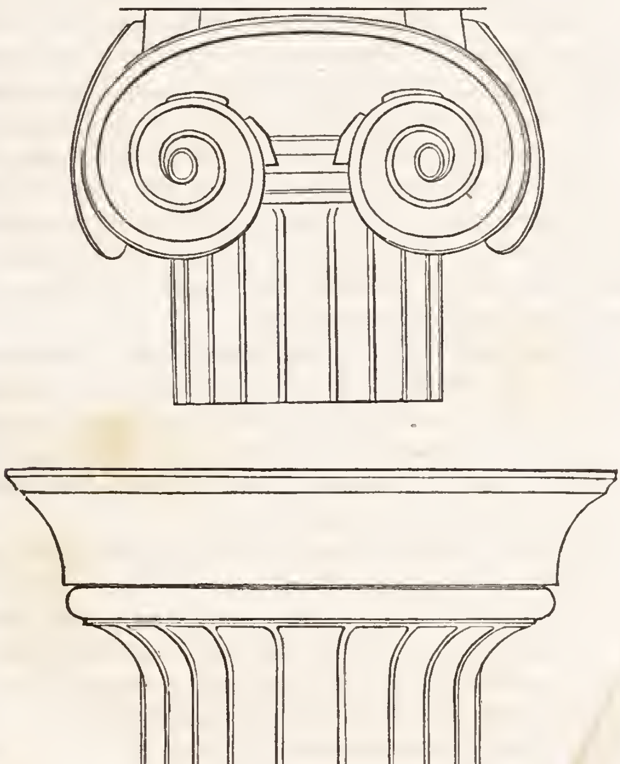


Fig. 6 shows the internal order of the Temple of Apollo at Bassae. It has four similar faces; yet if it so far agrees

with many Roman and Modern Ionic capitals, it differs from them totally in every other respect. The base is peculiar on account of its great simplicity and its expansion, spreading out below to considerable more than the upper diameters of the shaft. This differs from the proper Ionic base, which is greatly contracted in its lower moulding. Another peculiarity of the Temple at Bassae is the mode in which the shafts are fluted ; the fillets are exceedingly narrow, and the channels shallow and very slightly curved, which gives the shaft altogether a different character from that attending the usual mode of fluting practiced for this Order. In Greek examples the baluster side of the column had a series of wide channels with broad fillets between them, and where great richness was affected, as in the Ionic of the Temple of Erechtheus, at Athens, the fillets had an additional moulding upon them, carved into heads. In the Asiatic examples, on the contrary, and Roman ones also, the baluster side is usually cut into the form of leaves, bound together, as it were, in the centre, by a broad grin.

The base usually given to this order by the Greeks was the *Attic* one, consisting of two tori, divided by a *scotia.* The upper torus was sometimes fluted horizontally; at others, cut to resemble an interlaced chain-like ornament, now called a *guilloche.* Modern architects, however, invariably leave the upper torus of the base quite plain.

Ionic Antæ.—Without exactly agreeing with that of the column, the base does not differ from it very materially, except, indeed, in the Ilisus example, where it is lower than the other, and consists only of a shallow scotia, with a channeled torus above it. In the Erechtheum example, it is distinguished from the column-base chiefly by both the lower and upper torus being channeled. The capital, or, as it is more commonly termed, *anta-cap,* on the contrary, is differently shaped from that of the column, in consequence of having no volutes; wherefore, it is not by any means so wide, neither is it so deep. The mouldings, too, though of the

same character, are differently disposed. Still, the anta-cap corresponds with the capital as to plainness or enrichment, being either carved or not, as those of the latter happen to be; and, if the capital has an ornamented necking, so also has the anta. One singularity in the treatment of some antæ is that of the face of the anta, a slight break having been made down the middle of it, which causes it to appear composed of two very narrow faces, put together side by side, but not exactly flush with each other.

Ionic Entablature.—As expressed in the terms of the diameter of the column, that is, measured by it, the entablature exceeds that of the Doric Order. In the Parthenon, the entire height of the entablature is not more than two diameters; while in both the Ionic and Erechtheum, it is two diameters and seventeen parts, or two-thirds of a diameter more; whereas, it would seem that the Ionic column, being much more slender, the entablature ought to be less than two diameters in height, instead of being more. And so it is, and less in a considerable degree: it is the height of the entablature; in other words, the height of the latter must be in proportion to that of the former. Now, two and one-third diameters for the entablature is less in proportion to a column eight or nine diameters high. In the latter case, the entablature is equal to one-third of the column, and one-fourth of the whole order; but in the other two and one-third diameters, amount to only a fourth, or thereabouts, of the height of the column, and, consequently, to only about a fifth of the entire Order.

The Ionic *Archit ave* does not differ materially from that of the Doric. Its average or standard height is the upper diameter of the column. In the plainer examples of Ionic, such as the Ilissus one, the face of the architrave is quite plain, and distinguished from it only by the Doric tenia being converted into a moulding of a plain bead and small echinus, surmounted by a narrow tenia or broad fillet. In more decorated examples, as that of the Erechtheum, the face of the

architrave is divided into three surfaces or courses, called *faciae,* which very slightly project beyond or over-hang each other, and the moulding between the architrave and frieze is increased in depth; there is a greater number of mouldings, and some of them are enriched by being carved, or, as it is termed, *cut.*

As to the Ionic frieze, triglyphs being discarded for it, and no other characteristic members substituted for them, it becomes no more than a plain surface interposed between the architrave and cornice, unless, as is now never done, although it was, in all probability, generally done by the Ancients, it is enriched with figures in bas-relief, or other sculpture.

The Ionic cornice affords but little scope for further observation, more particularly in the Athenian examples, in which it consists of little more than the *corona* and cymatium above it, and some narrow *bed-mouldings* beneath the former member, partly got out of its hallowed soffit, or under-surface.

If the frieze is to be left plain, the best way would be to reduce its height a little, and perhaps that of the architrave also, and enlarge the cornice by introducing *dentels* into it. These *dentels* consist of a series of narrow, upright blocks (supposed to represent the end of joists), placed closely together; so that the spaces between them, which are only about half as wide as the blocks themselves, appear to *indent* that portion of the cornice, which, when introduced without being so ornamented, is called an uncut *dentel band.*

The Temple of Jupiter at Aizani, in Asia Minor, exhibits a remarkable example of the Ionic order, the details of which were recently published, for the first time, by M. Texier. In its general conformation, the base resembles the Priene example; but the entablature is quite different. The architrave is divided into three faciæ, separated by a cut moulding; and the upper faciæ is surmounted by an exceedingly deep and highly enriched course of mouldings. The frieze, too, is placed upon it at intervals, somewhat after the manner of the triglyphs, and connected with scrolls. The cornice

has both dentels and modillions, and a narrow corona, but a deep cymatium, enriched with carving.

Notwithstanding the superiority of the Greek Ionic to the Roman, it has not been adopted by the French and Italian architects of the present day. In England, the Greek Ionic has been employed almost to the entire exclusion of the other.

ROMAN AND MODERN IONIC.

As treated by the Romans, the Ionic capital was not only greatly impoverished, but deformed also,—impoverished by the volutes being greatly reduced in size, and consequently in importance also, as characteristic marks of the order,—and deformed owing to the tasteless treatment of it in other respects. Instead of the gracefully-flowing *festoon-hem*, or mouldings over the echinus, which seems to connect the two volutes, or sides of the face of the capital together, there is a straight line without any moulding to it; and the echinus, projecting before it, produces an appearance of clumsiness—of the several members not being properly adjusted to each other. As in all the Greek examples, the echinus of the capital, which passes behind the volutes, is invariably carved with that sort of pattern which workmen call "eggs and darts"—*ova*, or egg-shaped ornaments, almost naturally resulting from the contour of the moulding before it is cut; and the echinus of the Ionic, being always so carved, is on that account distinguished by the name *ovolo*—not because its section, or profile, is any portion of an oval or elliptic curve; for, among other things the Roman style differs from the Greek in having all its mouldings, both convex and concave, formed of portions of circles, by which its details become less elegant in contour.

There are but three accredited examples of the Roman Ionic Order as a whole, viz:—the Theatre of Marcellus, the Temple of Fortuna Virilis, and the Temple of Concord. Of

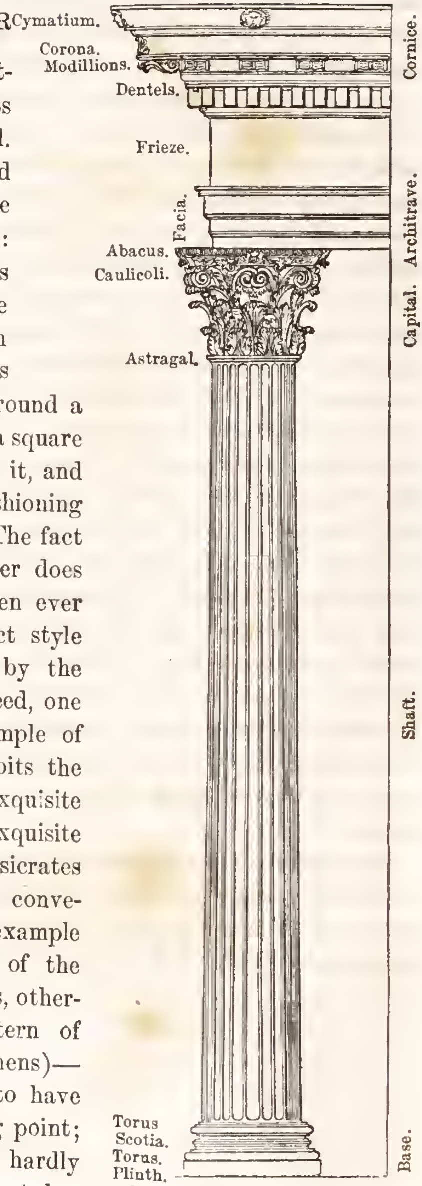
the first of these, the capital is the simplest and plainest, and also the smallest in its proportions ; that of the second is by far the best, its volutes retaining most of the Greek character; and that of the third is remarkable, if not for its ugliness in other respects, for its volutes being turned outwards diagonally, so as to present four equal spaces,—a mode afterwards *re-invented* and brought up as a novelty, by Scamozzi, in honor of whom it has since been distinguished by the name of the Scamozzi capital. There are in addition to these three examples numerous detached specimens of the Order in antique, concerning which our limits will not permit us to speak. The only other variety of, or *invention* for, the Ionic capital that we can notice is one that has been practiced by Italian Architects, and which may be distinguished as the *festoon* or festooned capital, the volutes being turned diagonally, and a festoon being suspended from the eye of one volute to that of the other beneath each face. This not only gives variety and richness to the capital, but by increasing its volume or bulk, increases its importance also, and produces great play of light and shade; there is harmony together with diversity in the combination of forms, the curve of the festoon being, though dissimilar, in agreement with the outline of the volutes. At present there is no proportion observed—that is with regard to decoration; for the same entablature or cornice at least is not equally adapted to large and small capitals. To obviate the meagreness and insignificance of the usual Italian Ionic capital, Sangovino and some others have frequently given it a necking, either plain or enriched, which even when plain, greatly improves the general appearance of the column by increasing the depth of the capital and reducing the height of the shaft. To make this clearer, without pretending at all to exactness, call the column nine diameters high, and the capital either half a diameter, or a whole one, accordingly as it is with or without a necking; now, in the first case, the capital will be to the shaft (base included) only as one to *seventeen*, whereas in the

other it becomes as one to eight, which is not at all too much, while the other way the shaft is much too lanky, and the capital too low,—as is probably felt by those who cannot explain the cause of such disagreement and disproportion.

ENTABLATURE.—The Theatre of Marcellus seems to have been the entablature which has guided the Moderns in the composition of their entablature, although they have greatly diminished the proportions of the cornice, which is there nearly equal to both architrave and frieze together. In the Athenian Ionic we may set down the architrave, frieze, and cornice as about 50—50, and 35 minutes respectively, making altogether two diameters and fifteen minutes ($2\frac{1}{4}$ diameters); therefore the cornice is to each of the other two divisions of the entablature only as 35 to 50. In the Roman Ionic, on the contrary, the cornice is by much the largest division; in the Fortuna Virilis example, the measures are—architrave 38′, frieze 19′, cornice 70′; in that of the Theatre of Marcellus 43′—36′—66′, making the entire entablature 127′, or 2 diameters 7 minutes. Although modern Architects vary from these proportions, and some of them make the frieze equal to, or more than the architrave, they all agree—in doctrine, at least, if not in practice—in making the cornice the largest division of the entablature. Either dentels or larger plain blocks, placed rather wide apart from each other, are considered the proper characteristic marks of the Ionic cornice.

The moderns have frequently given this Order, by way of distinction, a convex frieze, technically termed a pulvinated one, from its fancied resemblance to a cushion (*pulvinar*), whose slides swell out by compression when sat upon.

CORINTHIAN ORDER



The distinguishing feature of this Order is its deep and foliaged capital. The story usually related of the origin of the Corinthian capital is: the sculptor Callicrates was so struck by the graceful forms into which the leaves of the acanthus plant had grown up around a tall basked covered by a square slab, that he sketched it, and conceived the idea of fashioning the capital after it. The fact is, the Corinthian Order does not appear to have been ever matured into a distinct style and complete system by the Greeks. There is, indeed, one solitary Athenian example of Corinthian, which exhibits the utmost refinement of exquisite richness attempered by exquisite delicacy. In the Lysicrates capital—as we will for convenience call it (the example alluded to being that of the monument of Lysicrates, otherwise called the Lantern of Demosthenes, at Athens)—foliation may be said to have attained its culminating point; rivalled, it may be, but hardly surpassed. Still, it must be confessed, as a whole, that

Order leaves much to be desired for it, there being nothing of corresponding beauty and luxuriance in the rest of it. The cornice, for instance, is only a simple dentelled Ionic one; nor are any of the mouldings of the entablature cut. There was, however, in that particular case, above the entablature, what fully counterbalances and carries out the idea and expression of the capitals, namely, the ornamental roofing, and the matchless finial which crowns the structure, and produces a full climax of beauty and grace. Charming as the original itself is, or, more correctly, *was*, it has been copied and altered more than any other structure—often in a bungling manner.

The Corinthian Order may be thus described: the body of the capital is surrounded by two rows of leaves, eight in each row; besides which, there are four leaves, which, with the volutes over them, serve to support the four angles of the abacus. Although the Order itself is the most delicate and lightest of the three, the capital is the largest, being considerably more than a diameter in height,—upon the average about a diameter and a quarter. This, however, will cause the reader no surprise, if he bears in mind what has before been said as to the proportion to be observed between the column and its capital. The taller the former is, the taller must the latter be also, and so, far bulkier; although, while actually increasing in bulk, its tallness corrects the appearance of heaviness, by giving the *proportion* of slenderness. A capital whose height is only half a diameter, is, of course, by no means positively so bulky as one which is upwards of an entire diameter in height,—whereas the other is much higher than it is wide. The abacus is differently shaped from what it is in either of the other four Orders. In the Doric it is, as we have seen, merely a thick, square slab fitting the echinus beneath it, and left perfectly plain. In the Ionic, it is square; but its sides are moulded, whether it is square or not. The Corinthian abacus, on the contrary, is not, properly speaking, a square; although it may be said to

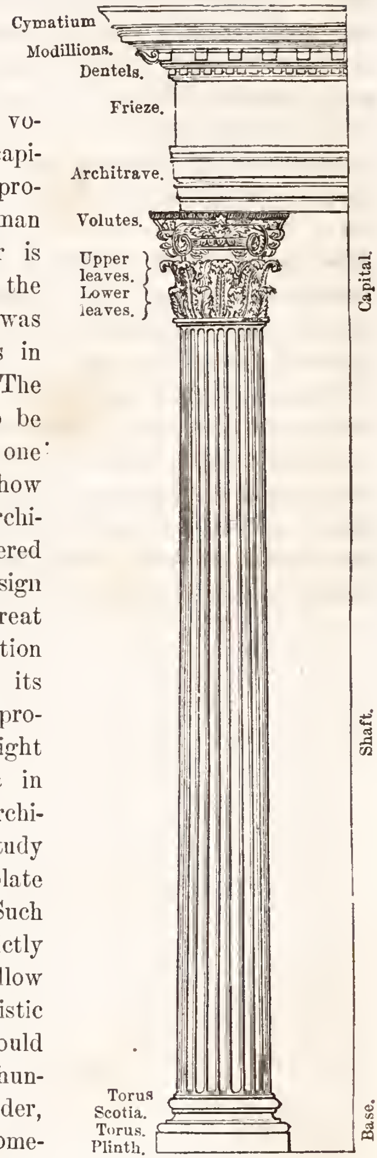
be so in its general form, inasmuch as it possesses *squareness*, having four equal sides. Instead of being straight, the sides of the abacus are concave in plan, being curved outwards, so as to produce a sharp point at each corner, which is accordingly cut off. Thus we find that the abacus here assumes a very different shape from its original one. The height of the capital varies from 60′ to nearly half as much again.

The proper Corinthian base differs from that of the usual Ionic or Attic, in having no smaller scotiæ, separated by two astragals; however, both kinds are employed indiscriminately, and the Attic is that which is generally used, except a greater degree of delicacy and richness than ordinary be required. As the shaft is fluted similarly to that of the Ionic column, viz., with twenty-four channels, there is nothing for notice or remark there, unless it be that the flutes are sometimes *cabled*, as it is called, that is, the channels are hollowed out for only about two-thirds of the upper part of the shaft, and the remainder cut, so that each channel has the appearance of being partly filled up by a round staff, or piece of rope, whence the term *cabling*.

Entablature.—The architrave is generally divided into three faciæ (the lower one much narrower than the others, which is rather contrary to architectonic principle, the weaker member being placed under heavier ones), with the mouldings between them, which, though frequently left plain, are properly enriched in the best and most consistently finished-up examples. We pass over the frieze, that being merely a single surface, either plain or sculptured. The cornice is larger than in the other Orders, larger as to height, and, consequently, as to projection also; which increased height and projection, and, we may add, increased richness, are demanded by the greatly enlarged bulk of the capital, and its more elaborate decoration. Examples vary so greatly, that we can give only approximating mean and average proportions, which may be set down at 2 diameters 12 minutes for the

whole entablature, and 54′, or something less than a diameter, for the cornice; but it is in many instances more, and, in others, as much less. As may be supposed from this greatly-increased depth of the cornice, it consists of a greater number of mouldings beneath the corona, for that and the cymatium over it invariably retain their places as the crowning members of the whole series of mouldings. To the dentels of the Ionic cornice is added a row of *modillions*, immediately beneath and supporting the corona. These modillions are ornamented blocks, curved in their under surface, after the manner of the letter S turned thus, ∽; and between them and the dentels, and also below the latter, are other mouldings sometimes cut, at others, left plain. Sometimes a plain, uncut *dentel-band* is substituted for dentels; sometimes, in simpler cornices, that is omitted altogether, and plainer blocks are employed instead of modillions; or else both dentels and modillions are omitted, as in the Temple of Antoninus and Faustina, notwithstanding that it is considerably enriched —even the face of the corona being fluted.

COMPOSITE ORDER.



This Order is not considered by some modern writers as an Order. The volutes at the angles of the capital are expanded into the proportions of those in the Roman Ionic capital. The Order is without doubt derived from the Ionic and Corinthian; it was first used by the Romans in their triumphal arches. The very dissimilar varieties to be met with, all belonging to one and the same Order, show plainly enough that the Architects of antiquity considered themselves at liberty to design their own detail, and to treat an Order as a composition marked out for them in its leading forms and general proportions, but which they might fashion nearly *ad libitum* in other respects. Modern architects are more apt to study mere convenience, and violate architectural orthodoxy. Such architecture may not be strictly classical; but it does not follow that hence they are not artistic or beautiful. If our limits would permit, we could instance hundreds of examples of this Order, each of which might be somewhat different from the other; and perhaps it might lead

the reader to the conclusion, that the Composite should be considered not as a separate Order, but as a modification of the Corinthian.

COLUMNIATION.

Columns and entablatures, in themselves, do not, properly speaking, constitute an Order, although they serve as specimens of it. They must enter into, and regulate the organization of a structure, before they can become, by composition, what is strictly termed an Order. As exhibited in their temples, the system of columniation practised by the ancients was strictly organic and natural. Instead of being something accessory, supplementary to, and independent of, the fabric, that might be either omitted or applied at pleasure, as commonly practised in Italian and modern composition, the Order itself constituted the exterior of the building, at least of that side or front of it where it was introduced, when it was not continued throughout; so that the Order and its dimensions, once established, and the mode of inter-columniation determined, the edifice shaped itself. Before we enter upon the subject of inter-columniation, it will be desirable to explain the various forms of temples, and the technical terms by which they are distinguished.

The *naos*, or *cella*, as it is more usually called, or temple itself, was comparatively small, even where the entire mass was of considerable size, gradual extension of size being produced not so much by any great enlargement of the interior as by external columniation and its gradual development. It is probable that the earliest Greek temples consisted of the *naos* only, and were accordingly plain ASTYLAR buildings, or without columns, except in front or at the entrance end, where an enclosed porch was formed by introducing columns, by continuing the side walls, and placing columns between them *in antis*, that is, between the two *antae* or pilasters forming the ends of those walls. The next step seems to have been to advance the porch before the

main building, instead of keeping it recessed within the side walls, thereby converting in form a portico in antis into a *prostyle,* or projecting line of columns; thus a *distyle in antis,* or a portico consisting of two columns between antae, consequently of three *intercolumns,* or open spaces between the antae and columns, would become a *tetrastyle,* or projecting portico of four columns. By the other end of the building being similarly treated, the temple became *amphiprostyle,* or prostyle at both ends, in rear as well as in front, the sides still remaining *astylar.* The next and last style of advancement was to continue columniation all round, enclosing the *cella* within colonnades along its sides as well as at its ends, which disposition of plan is expressed by the terms *peristyle* or *peristylar,* and peripteral, which of necessity produces two columns and two intercolumns more in front; for what would otherwise be merely a tetrastyle prostyle, with four columns and three intercolumns, (the number of the latter being always one less than of the others,) becomes by the colonnades being continued along the side, a hexastyle (six columns and five intercolumns); or if originally a prostyle hexastyle, it would be rendered an *octastyle,* (eight columns and seven intercolumns,) and so on. It should be observed, too, that a building cannot at the same time be *peristylar* and have a *prostyle* portico, the latter being merged in the general columniation, instead of projecting from the rest of the edifice as a distinct feature. Of peristylar temples there were two sorts, viz. : those with a single row of columns on each side, and those which have two, which last are distinguished by the term *dipteral,* *i. e.* having two wings or *aisles* on each side. Although it did not at all affect the general appearance, notwithstanding that it extended the plan by adding two more columns and intercolumns to the front, this last-mentioned mode was attended with greater richness of columniation, and the intercolumns contributed not a little to variety of effect and play of perspective; besides which, greater sheltered space was gained for ambulatories; whereas

in the usual simple peristyle, where the space between the outer columns and the walls of the cella was limited to the width of a single intercolumn, the side colonnades were mere narrow passages, very little wider—at least in Doric temples—than the diameter of the columns themselves, consequently of very little actual service. In what is called the *pseudo-dipteral* mode, more of clear space between the colonnades was provided by omitting the inner columns, which mode reduced the plan to that of simple peristyle, the only difference being, that instead of the width of a single intercolumn, a clear space, equal to two intercolumns and one column, was gained for the ambulatories. The Temple of Jupiter at Silenus was of this description, and being only octastyle in front,—the least possible width for a dipteral or pseudo-dipteral plan,—of the seven front intercolumns, for four (*i. e.*, two on each side) were given to the lateral colonnades, and only three left for the breadth of the *cella*, which must have looked like a smaller edifice standing within a colonnaded and covered enclosure.

The above few and simple arrangements of plan are nearly all the varieties that the Greek temple style offers; and some of them are little better than distinctions without differences, inasmuch as the differences do not affect general external appearance. Peripteral, dipteral and pseudo-dipteral, all agree in the main point, and the two latter answer to the name of peripteral as well as to the first, being merely modifications of it. Great as were its æsthetic beauties, Greek Architecture was—why should we scruple to confess it?—exceedingly limited in its compass and power of expression: what it did, it did admirably, but it confined itself too much to one idea. "When you have seen one green field," says Johnson, "you have seen all green fields;" and so we may say of Greek temples,—when you have seen one of them, you have seen all of them. However they may differ from one another as to the treatment of the Order adopted for them, the number of their columns and mere particulars of

that kind, they resemble each other very nearly in all leading points. Not only were their plans invariably parallelograms, but alike also to proportion, forming a double square, or being about twice as much in length as in breadth; for so exceedingly *methodical* was the Greek system, that the numbers of columns on the flanks or sides of a peripteral temple was regulated and determined by the number of those in front. The number of those in front was invariably an even one, as otherwise there would be no middle intercolumn; but on the flanks of the edifice, where there was no entrance, the number of the intercolumns was an even, and that of the columns an uneven one, so that a column came in the centre of these side elevations.

As to the mode in which the front influenced the sides by determining the number of columns for them, the established rule seems to have been to give the flanks twice as many intercolumns as there were columns at each end: thus, the Parthenon, which is octastyle, has *sixteen* intercolumns; consequently, seventeen columns on each flank. In like manner, a hexastyle temple would have *twelve* intercolumns, and thirteen columns on its sides. There are, however, exceptions; for instance, the temple at Selinus, which has been mentioned as an instance of the pseudo-dipteral mode of columniation in an octastyle, with sixteen, or just twice as many columns on its sides as in front; consequently, the intercolumns are only fifteen, and being uneven in number, there is a middle one, as in the front itself. After all, the difference caused by there being an intercolumn more or less than usual, is but a very slight one, such as is to be ascertained only by counting the columns, and such as not to cause any perceptible difference in the general physiognomy of building.

Besides the restriction as to general proportion of plan, namely, the fixed relationship between the length and the breadth of the building, proportion with regard to height was limited in a different way, and in such manner that the character of increased richness and importance derived

from a greater number of columns was attended not, indeed, by decreased height, but by *decreased loftiness*, or *proportional* height, that is, height as measured by either breadth or length. Paradoxical as this may sound at first, nothing can be more plain when once explained. Discarding nicety in measurement, we will call a *tetrastyle* portico about a square in height—that is, about as high as wide; but add four more columns, extend it from a tetrastyle to an octastyle, so that it becomes about a double square in breadth, or twice as wide again, and the inevitable consequence is, that it is then only twice as wide as high; that is, as to proportion, only half as *lofty* as it was before. The expression of loftiness, in which altitude greatly predominates over breadth, was quite beyond the reach of the Greek system. Their temples might be planted on lofty eminences, but the structures themselves never towered upwards. As far as it went, their system was perfect—so complete, indeed, in itself as to be unfit for almost any other purposes than that for which it was expressly framed.

If the Romans corrupted the Doric and Ionic, they developed and matured the Corinthian Order, and also worked out a freer and more complex and comprehensive system of Architecture. To say nothing of their introduction and application of those important elements of both construction and design, the arch and vault, which hardly belong to a mere treatise on the Orders, it is to the Romans that we are indebted for varieties and combinations of plan that will be sought for in vain among Grecian structures. Of the Romans it may be said, "*Mutant quadrata rotundis.*"

Circular forms, and curves displaying themselves not only in elevation and section, but in plan; and while, among the Greeks, Architecture was confined almost exclusively to external appearance and effect, in the hands of the Romans it was made to minister to internal display of the most enchantingly picturesque kind, as would be amply attested by the Pantheon alone. In that edifice, and Hadrian's Mausoleum

(now barbarized into the Castello di S. Angelo), the cylindrical form was exhibited upon an imposing scale; in the temple at Tivoli, in far less dimensions, but with the most captivating taste; and again in the tomb of Cecilia Meletta, we have a fine example of an unbroken astylar circular mass.

In such structures as the Colosseum and other Roman amphitheatres, a different form of curvature, namely, the ellipses, was employed with admirable propriety and effect. In the interior, again, we find the hemicycle or concave semi-circular form, both frequently and variously applied by Romans in such edifices as their Baths, which afford many excellent studies for combination of *plan*.

To enter into the system of Roman Architecture as the subject would require, would very far exceed our present limits and purpose ; much less can we pretend to treat here of the still more varied and complex Italian, or Modern European system, into which *fenestration* so largely enters, *columniation* being, more frequently than not, subordinate. Were we to touch upon the last mentioned style and its various elements, it could be only so superficially as to be more disappointing than instructive. Better that our reader should admire our forbearance, than complain of our unsatisfactory jejuneness. We may, however, permit ourselves to throw out one or two general remarks ; the first of which is that it is a great error to confound with the Italian the two Ancient Classical styles, applying to them alike the epithet "Grecian," merely in contradistinction to Gothic, or Mediæval Architecture. It is absurd to pretend to test by the Greek style, one so totally differently constructed as the Italian ; an error that could hardly have been fallen into but for the practice of applying the same names to very different things. The term Order has quite a different meaning as applied to the original classical mode of the Art, from what it has in the other. In Italian composition, an Order is more frequently than not, mere decoration in the shape of columns and entablatures, fashioned *secundum artem*,

(a very different thing from artistically,) so as to resemble in detail, and certain conventional distinctions, those of the Ancients. Infinitely better would it have been, if, instead of allowing themselves to be misled by the pedantry of Vitruvius, the Architects of the so-called Revival, who showed much happiness of invention in other respects, had treated the Orders freely; or perhaps still better, had they worked out ideas of their own for columns and entablatures, whenever they had occasion for them, either as matters of necessity, or as mere decoration. Had Italians allowed themselves greater latitude in that respect, they would, in all probability, have been far less licentious upon the whole than they frequently were, and their buildings would have been more homogeneous—more of a piece. But they, forsooth, be one of the Orders or all of them at once, and a great deal else in the bargain. Therefore the affecting to retain the Ancient Orders in their purity, served no other purpose than that of making all the more evident how completely their first intention and character had been lost sight of.

The clinging with scrupulous punctillo to what had become dead-letter forms, after the system which they had produced had been abandoned, and exchanged for another and widely different one, was merely superstition and pedantry. It might show acquaintance with traditional learning and the writings of Vitruvius ; but it also showed dulness of æsthetic feeling, or, what is not much better, deficiency of æsthetic power. There was, however, one mode of applying columns, which, although generally regarded as the most licentious and un-orthodox, nay, even preposterous, because quite contrary to all classical practice and precedent, has at least one propriety, that of being rational, since columns there officiate as columns—as real support ; whereas in a great deal of Modern Architecture, that is admired for the correct taste it displays, columns and their entablatures are mere expletives, instead of actual compo-

nent parts of the fabric, and simulate a mode of construction neither required for nor practiced in the fabric itself.

The particular mode here alluded to is that in which arches are not introduced together with columns, but the arches are not only introduced together with colums, but the arches and columns are so indissolubly married together that they cannot be divorced, inasmuch as the arches are supported by the columns themselves, the former springing immediately from the capitals of the latter. Such combination, it might be supposed, would be gladly admitted as sufficiently legitimate, both because in accordance with rational architectonic principles, and because it greatly extends the resources of the Art ; nevertheless such is the omnipotence of prejudice, that instead of being welcomed and adopted by us, it has been decried as a barbarism. As an irresistible and crushing argument against it, we are told that columns were not *originally* intended to be so applied; —admirable logic, truly ! There are a great many other things besides columns which have in course of time come to be applied to uses not originally contemplated. In regard to that combination of columns and arches according to which the latter spring immediately from the others, and are supported by them, there are two questions : the first and practical one, Do the columns afford sufficient support? the second and æsthetic one is, Is there also sufficient appearance of support ; or is there anything contradictory to principle, to judgment and good taste ? The first question needs no answer, since it answers itself ; it being an indisputable fact that columns so employed do answer the purpose to which they are turned. The other question is not so easily answered : the prejudiced will of course answer it according to their own contracted taste and narrow notions, condemning the mode alluded to, without any inquiry into its merits and advantages, merely on the ground of its being quite at variance with the classical system of *trabeated* columniation, that is, with columns supporting a

THE ACROPOLIS

page 266

horizontal architrave and entablature, or general horizontal trabeation. That by the substitution of arches for architraves, the character of the Greek system is forfeited, cannot be denied ; but then another character is established whose difference from the original one ought not to be made its condemnation. To demand of a different mode that it should resemble and conform to the laws of that from which it differs, is absurdity in the extreme, for it is requiring at once that it shall be a different one and the same. To compare different styles is a very useful sort of study ; but to make any one style the criterion or standard by which others are to be judged, is preposterous.

The style in which the arch and column enter into direct combination with each other, and for which there is no specific name, has at all events some economical recommendations, inasmuch as shorter columns, and fewer of them, are required, than would be necessary for the same height and length according to the trabeated mode. In itself, too, it possesses much capability ; yet as is the case with every other style, the merit of the works produced in it depends upon the manner in which it is treated, and the talent brought to it. There is no style of the Art so poetical that the flattest prose may not be made out of it ; and hardly any so utterly prosaic as to be incapable of being kindled into poetry by the Promethean torch of generality—artistic treatment, and *con amore* æsthetic feeling.

INTERCOLUMNIATION.

Although Intercolumniation consists only in regulating and determining the spaces between the columns, and consequently does not affect the nature of the composition, for a tetrastyle, hexastyle, &c., would still be such, no matter how narrow or wide the *intercolumniations* or intervals between the columns may be, very much depends upon it with regard to expression and effect. How intercolumniation is regulated

in the Doric Order, has already been explained: in that the distances between the columns is generally governed entirely by the triglyphs of the frieze, so that there can be no medium between *monotriglyphic* and *ditriglyphic* in intercolumniation, accordingly as there is either one or two triglyphs over each intercolumn. But in the other orders there are no such restrictions: in them the intercolumns may be made wider or narrower, as circumstances require, but, of course, under the guidance of judgment and good taste; for what is left *a discretion* is not always very discreetly used. Vitruvius and his followers, however, have not cared to trust to discretion or indiscretion, but have fixed certain positive or distinct modes of intercolumniation, viz., five, to wit:

Pycnostyle, or *closely set*, in which the intercolumns are one diameter and a quarter or a half in width.

Systyle, in which they are two diameters wide.

Eustyle, or *well spaced*, in which they are two diameters and a half.

Dyastyle, in which they are three diameters.

Aræostyle, or thinly set, in which they are four diameters.

Let us repudiate for Architecture all such formal, Act of of Congress legislation, and take pycnostyle and ærostyle as the greatest allowable degree of distance or closeness at which the columns can be placed, and it follows, that between such maximum and minimum, any intermediate measure is admissible, and that there is no occasion to fix it positively and arithmetically, and make distinctions which are, after all, only arbitrary. There are a great many matters in design which must be left to the architect, and intercolumniation is one of them. It is impossible to have precise rules for every thing, neither is it desirable; for, if everything in it could be done by rule, Architecture would forfeit its nature as one of the fine arts, and be reduced to one of the mechanical. What is done by rule can be done just as well as by one as another.

Excepting the terms pycnostyle and aræostyle, which are useful as expressing the greatest degree of closeness or of

openness of inter-columniation consistent with well-proportioned arrangement, the others may be dispensed with. To designate one mode as *eustyle, par excelence*, is very much like saying that the proportions assigned to it, viz., 2·30′, or $2\frac{1}{2}$ diameters, are the very best, and all the rest comparatively defective; according to which doctrine, the *monotriglyphic* mode of inter-columniation usually employed by the Greeks in their Doric temples, and which answers to the character of pycnostyle, is not so well-proportioned as what is emphatically called eustyle. Let it be whatever it may, as expressed in terms of the diameter of the columns, inter-columniation should always deserve the name of eustyle, or *well-proportioned*, by being such as satisfies the eye, and contributes to the particular character that befits the occasion, and harmonizes with the other *proportions* of the structure. Pycnostyle, or close spacing, carries with it the expression of both richness and strength, the solids, or columns, being very little less than the voids or inter-columns. Aræostyle, or wide spacing—and ditriglyphic Doric inter-columniation may be called such—produces an effect of openness and lightness, but also partakes of meagreness and weakness, owing to the want of sufficient apparent support for the entablature—a very frequent fault in modern architecture, where frugality as to columniation has often been allowed to produce a degree of poverty, which contrasts very disagreeably with that of the decoration affected by the Order itself. Inter-columniation ought to be made to depend, in some measure, upon the nature of the composition: a tetrastyle portico, for instance, or a distyle in antis, admits of wider inter-columniation than would be suitable for an octrastyle; because pycnostyle, where there are only three inter-columns, would produce too great narrowness of general proportions for a portico.

Hardly is there need for observing, that, be their proportions what they may, the inter-columns in a colonade or portico must be all alike; nevertheless, in a Grecian Doric

portico there is, as we have seen, some difference, the two extreme inter-columns being there narrower by the width of half a triglyph. There is, besides, another exception from the general principle; for the centre inter-column of a portico was frequently made somewhat wider than the others, in order to mark the entrance, and the better to display and afford greater space for access to the door within.

One mode of columniation and inter-columniation which remains to be spoken of, is that which has been sometimes practised by modern architects, and combines the two extremes of pycnostyle, or still closer inter-columniation and aræostyle. This consists in coupling the columns, and making a wide inter-column between every pair of columns; so that, as regards the average proportion between solids and voids, that disposition does not differ from what it would be were the columns placed singly.

Although denounced by some critics, more especially Algaratti, as altogether licentious and indefensible, and although it is not to be specially recommended or indeed practicable on every occasion, the coupling of columns may, under some circumstances, be not only excusable, but advisable and proper. As is the case with almost everything else in matters of art, all depends upon *how* it is done, and whether with or without sufficient reason. That there is no classical authority for it, is no valid reason against it; in the constitution of the ancient temples there was nothing to require or *motive* it. It may be conceded, however, that coupled columns, forming a prostyle surmounted by a pediment, are objectionable; because where so strong a resemblance to the antique model is preserved in other respects, a departure from it in regard to the disposition of the columns has a disturbing effect.

Having gone through the Classical Orders, and explained their elements and constitution, we have performed as much as we purposed or as we promised. Within the same compass we might, no doubt, have touched upon a great deal

besides that to the study of Greek and Roman Architecture, by restricting ourselves to bare matter-of-fact, and suppressing all comment, and so treating the subject drily and superficially. Proceeding upon the principle *multum haud multa*, we have aimed at nothing more than to initiate the reader in such a manner as to excite interest in the subject and stimulate further inquiry. Should we have effected that, we shall have gained our purpose. Although the Orders have been classified according to the old division, the reader must remember that it is not expected that he shall be a plodder who works by rate and routine. Much, very much indeed, will have been learned by the reader, should he have learned, or have been put in the way of learning, to look upon those various compositions in the several Orders, not *merely* with eyes of a Builder or a Mechanic, but with the intuition and the feeling of an Artist; in short, to look upon them as general *types* to be diligently studied, and then imitated with congenial gusto

BOOK II.

SKETCHES OF THE HISTORY AND DESCRIPTION OF THE STYLES OF ARCHITECTURE OF VARIOUS COUNTRIES, FROM THE EARLIEST TO THE PRESENT TIME.

CHAPTER I.

Architecture of various Countries.

In an attempt to trace the origin of Architecture, with a view to a history of the Styles that prevailed in this and other countries, it will be quite unnecessary to give any account of the different kinds of tents, huts, and other timber erections used as the early habitations of mankind, resulting from the necessity of protection from the inclemency of the seasons, and which required little skill or knowledge of construction. Our purpose is to refer only to such ancient erections of durable materials as evince a knowledge of some systematic construction, or were the source from which proceeded all that can properly be called Architecture.

Nineveh, Babylon, and Egypt.

The first city that contained solid and durable edifices was Nineveh, the capital of the Assyrian empire and the residence of the Assyrian kings, founded by Asshur, the great-grandson of Noah.* Jonah speaks of it as an exceeding great city of three days' journey:"† it is described by Strabo as larger than Babylon: the walls, according to Diodorus, were 100 feet high, and so broad that three chariots might be driven on them abreast: upon the walls stood 1500 towers, each 200 feet in height; and the whole was so strong as to be deemed impregnable. That this city must have been one of great grandeur at a very early period, there can be little doubt. It is mentioned as a place of great commercial importance, and

* Genesis x. 11. "Out of that land went Asshur, and builded Nineveh."
† Chap. iii. 3.

"its merchants as more than the stars of heaven." Nineveh was taken by the Medes under Arbaces, in the eighth century B.C., when it was nearly destroyed; and quite so, when taken by Cyaxeres, 625 B.C. All that now remains on each side of the Tigris of this once splendid city, has the appearance of a range of hills, from which large stones and bricks connected with bitumen, on which are inscriptions, are frequently dug up.

The next city noted for its early origin was Babylon, founded by Nimrod, son of Cush, and grandson of Ham.* It is described by the ancient writers, Strabo and Quintus Curtius, as a city of great strength and magnificence. So great was the circuit of its walls that there was pasture and arable land within them sufficient to support the whole population during a long siege. According to Herodotus, the walls were 50 cubits thick and 200 in height, built of bricks made from the earth which was dug out of the ditch that surrounded the city. In the walls were 100 gates made of brass, as well as the jambs and lintels. It has been said, that if there was a city which seemed to bid defiance to any predictions of its fall, that city was Babylon, for a long time the most famous city of the old world, whose walls were reckoned amongst its wonders.

The ruins that have been discovered on each side of the Euphrates confirm the accounts which have descended to us of its splendor, although nothing now remains but large masses of brick-work laid on lime mortar of good quality. On the eastern side, it is supposed, are the remains of the great temple of Belus,† which, according to Diodorus, was higher than the largest pyramid. Among the ruins are to be found fragments of alabaster vessels, fine earthenware, marble, and great quantities of varnished tiles, whose glazing and coloring are still fresh

* Genesis x. 10. "And the beginning of his kingdom was Babel."

† The temple of Belus, as described by Herodotus, was of a pyramidal form, similar to the Hindoo temple at Tanjore, and the great Mexican temples. It was founded by Semiramis, 1650 B.C.

Of what date these are, it is impossible to conjecture, as so little information exists on this interesting subject. We are told that in the time of Semiramis, Queen of Assyria, 1665 B. C., an extensive and splendid palace existed on each side of the Euphrates, connected by a tunnel under the river, and likewise that a bridge was built by Nitocris to connect the two parts of the city divided by the Euphrates. The piers were of large hewn stones, in order to erect which the course of the river was diverted, and its bed left dry.

The city was brought to its highest degree of perfection by Nebuchadnezzar, about the year 600 B. C.; but its splendor must have been of short duration, as about 60 years after the death of that monarch, and during the reign of Belshazzar, it was taken by Cyrus. From that time it gradually declined, and afterwards became a part of the great Persian monarchy.

The Egyptian Thebes,* situated near the southern extremity of that empire, is the most ancient city of whose buildings any remains exist at the present time. The period of its foundation ascends, probably, to the same antiquity as that of Nineveh and Babylon. It was the first seat of the Egyptian government,† which, at an early period, was transferred to Memphis, near the northern extremity of the empire. From this time, its importance declined; but the imperishable nature of the materials, and the immensity of its masses, have preserved the buildings for more than three thousand years. Memphis, less fortunately situated, by being nearer the line of communication between Asia and Africa, has been more subject to the destructive caprices of man, and has disappeared from the face of the earth.* At

* The most ancient name of Thebes is Pathros, and it was so called from Pathruism, son of Mizraim and son of Ham. Mizraim was the first occupier of the country of Egypt.

† The first king mentioned is Menes, who is supposed to have lived 2000 B.C., and contemporary with the era of the Chinese emperor Gao, with whom the historical period of China begins.

* Egypt was conquered by Cambyses, 525 years B. C.; after which time it became a province of Persia.

present the site of the city of Thebes is occupied by four principal villages,—Luxor and Karnac on the eastern side, Gournah and Medinet-Abou on the western side of the river. The buildings and sculpture of this gigantic "city of a hundred gates," still extant, are the most ancient that exist in Egypt, and are the best and most genuine specimens of Egyptian art and architecture; for there is every reason to believe that by far the greater part were executed before Egypt had yet experienced the influence of the Greeks, and long before the Persian invasion.

The ruins, chiefly consisting of temples, colossi, sphinxes, and obelisks, occupy nearly the whole extent of the valley of the Nile, a space of six miles from east to west. On the western side, where the ruins of this vast city terminate, those of the "city of the dead" commence, among which there are tombs excavated in the rocks, and decorated with paintings—still as fresh as though the artist's hand had been engaged upon them but a few weeks past.

The principal remains of Egyptian architecture (chiefly temples) are to be found on the banks of the Nile, and extend from Cairo to Nubia, a distance of 500 miles. The peculiarity observable in all, is the great sublimity of the masses, the grandeur and severity of every line, by which their buildings bear the stamp of that sentiment of eternal duration which they were always so anxious to realize in their monuments.

At a very early period the Egyptians were extremely skilful in working stone, an art in which they have never been surpassed. The large blocks of stone of which their temples are composed are well squared, and so laid that the joints are scarcely visible.

The most interesting and complete temple in the whole valley of the Nile is that of Edfou, about 25 miles above Thebes. This great and magnificent temple is one of the largest in Egypt, and is in comparatively good preservation. Its form is rectangular, and its general dimensions 450 feet

by 140 feet. In the centre of one of the sides is the entrance between two sloping towers, 100 feet in length by 32 feet in width, on the surface of which are represented some colossal figures; and above these are two rows of smaller ones, supposed to be the divinities of the temple, receiving the offerings of the Ptolemies. Within is a court, surrounded by a colonnade on three sides, and on the side facing the entrance is a beautiful pronaos or portico, of eighteen columns: beyond this is another of smaller dimensions; and further on are the walls which protect the sanctuary and its dependencies: these are so completely filled up with sand and soil, that it is nearly impossible to reach them. All the columns, friezes, and cornices, and the whole surfaces of the walls, inside as well as out, both of the pronaos and court, are covered with symbolical sculptures, hieroglyphical inscriptions, and representations of offerings to their divinities.

Of all the works of the ancient Egyptians, those which have caused the greatest wonder to the world at large are the Pyramids of Gizeh, supposed by Sir Gardner Wilkinson to have been erected 2120 years B.C.* Herodotus dates the Great Pyramid about 900 years B.C., or about 450 years before he visited Egypt. Chevalier Bunsen places them about 2000 years before that period; and this is confirmed by the opinions of Champollion and Rosellini.

The Great Pyramid, said to have been built by Cheops,† is 700 feet square at the base, and 470 feet in height; the second is 650 feet square, and 160 feet in height; the third, 400 feet square, and 160 feet in height. About 300 paces from the second pyramid stands the gigantic statue of the Sphinx, whose length, from the forepart to the tail, has been found to be 125 feet. Belzoni cleared away the sand, and found a temple between its legs, and another in one of its paws.

The mechanical skill of the Egyptians is shown in their quarrying and working stone; and the means that must have

* And attributed by him to Suphis and Sen-suphis.

† The other two by Cephrenes and Mycerinus.

been used to convey such immense blocks of stone as we find in their works, from quarries situated at a distance from them, naturally surprise us.

The obelisks of Thebes and Heliopolis vary in size from 70 to 93 feet in length,* and are built of one stone. The largest in Egypt, which is at the great temple at Karnac, is calculated to weigh 297 tons, and was brought about 138 miles from the quarry. Those at Heliopolis passed over a space of 800 miles.

The two colossal statues in a sitting attitude (one of which is the vocal Memnon), are each of a single block, 47 feet in height, and contain 11,500 cubic feet: they are carved from stone not known within several days' journey from the place where the statues are found; and at Memnonium is a colossal statue, which, when entire, weighed 887 tons. The raising of the obelisks is considered a far greater test of mechanical skill than the transport of these prodigious weights; but into the mode that was adopted we have no insight from any representations yet discovered.

Of the taste, style, and character of Egyptian Architecture, little can be said beyond admiration at the immensity of the works, and the patience with which they must have been accomplished.

The masses of material which the country produced measured their efforts and conceptions, and their invention was exhausted by a very restricted number of combinations.

Their monuments are admirable for grandeur and solidity, and they have a truly imposing effect; but we can only consider them as part of the history of Architecture and Art, because the ornaments and sculpture, originating from a symbolical religion peculiar to the Egyptians, admit of no revival, even were art more immediately connected with them.

The columns are evidently a representation of a bundle of reeds or lotus-stems, tied together at the top and base, the

* Sir Gardner Wilkinson's "Manners and Customs of the Ancient Egyptians."

leaves of which, as well as those of the palm, are chiefly used in ornamenting the capitals.

CHAPTER II.

Grecian Architecture.

ARCHITECTURE and Art have been always progressive, and have not appeared at once in full perfection; yet, in our admiration of their perfection, we do not always consider the history of their progression, or the sources from whence they sprang. No style, with the exception of the Egyptian, was the spontaneous growth of the soil on which it flourished, or proceeded directly from the nations that practised it; the the germs of all other styles were borrowed from people whose habits and religious customs were totally dissimilar; and its advances or improvements were the natural results of civilization, caused by intercourse with other nations in times of peace, or by the adoption of all that was worthy of imitation in conquered states, during the incessant wars that were carried on in the eastern parts of the world.

Thus was it with the much-admired Architecture and Arts of Greece and Rome, so that centuries elapsed ere any thing worthy of those terms was to be found in either empire.

Greece was divided into a number of petty states, which, independent of each other, and, therefore, necessarily rivals, surrounded themselves, as a means of protection, with thick walls, long before they had learned the art of building temples, and when their huts or houses were of the rudest character. The first erections were their acropoles, invariably situated on eminences which were converted into citadels, and served for places of security when the population became too numerous to remain in them, and had spread themselves over the surrounding plains. The acropoles usually contained all things of the greatest value to the community, such as the public treasures, the archives, and the temples of the tutelary

divinities; indeed, they were to the Greeks what the capitol was to the Romans.

The oldest remains of walls and acropoles exist at Tiryns, or Tyrinthus, and Mycenæ, near Argus, in the Morea, and are said to have been built by the Cyclopes, a tribe which is supposed to have arrived from Thrace or Phœnicia, and settled in Asia Minor. The date of the masonry is supposed to be coeval with the time of Abraham, who arrived in Canaan B. C. 1917.* Sir William Gell makes the date of the buildings B. C. 1379. All that at present exists of Tiryns consists of portions of the walls of the acropolis, which are from 21 to 25 feet in thickness, and 45 feet in height, built of tremendous blocks of stone, from 10 to 13 feet long, and 4 feet 4 inches thick. In the thickness of these walls are two ranges of galleries, each 5 feet broad and about 12 feet high: the shape of these passages is triangular, the sides sloping upward until they meet. This form was obtained by making the horizontal courses of masonry project one beyond the other, the edge of each course being splayed off so as to give, from the interior, very much the apppearance of a kind of arch having been constructed. They probably conducted round the whole of the citadel, and were used as shelters for the garrison during the night or bad weather. Mr. Woods† says, that no tool seems to have been applied to the stone, but that the rude masses are merely heaped on one another, taking care in the position of each successive block to place it where it would most exactly fit into the work, and most probably keeping the smoothest side outwards to form the face of the work. The workmanship of these walls is nothing more than that of the modern fencing without mortar, the interstices between the larger stones being filled up with others of smaller size, unworked, and merely heaped on one another. Pausanias informs us, that when the Argives attempted to destroy Tiryns, the walls were so strong that they could not throw them down: he also describes them

* Fosbroke.

† "Letters on Architecture," 2 vols. 4to.

to be equally worthy of admiration with the Pyramids of Egypt.†

The next city connected with Greece that demands our notice, on account of its early fortifications and acropolis, of which parts exist at the present time, is Mycenæ, near Argos, likewise built by the Cyclopes, or by Mycenæus, B. C. 1700, and considerably enlarged by Perseus about B. C. 1390. The walls of this city, like those of Tiryns, are in some places built of rough stones, from 8 to 9 feet in length: when entire, they must have been 60 feet high, although at present, in the most perfect part, their height is only 43 feet. The general thickness is 21 feet, but in some places 25 feet, and they are mostly coustructed of well-jointed polygonal stone. Some remains of towers are discernible.

"The Gate of the Lions" owes its celebrity to the basso-relievo by which it is surmounted, the subject of which is two lions, with their fore-paws resting on a pedestal: from this the gateway takes its name. This sculpture (on a triangular stone over the architrave) is the most ancient specimen of this kind of Grecian art; it is 10 feet 6 inches wide at the base, and 9 feet in height: between the lions is a semi-circular pillar, bearing some resemblance to the Doric Order, although, contrary to the general usage, it increases in size from the bottom to the top. The date of this sculpture is supposed by some to be nearly coeval with the other part. Pausanias mentions, that in his day it was reported to be the work of the Cyclopes: however this may be, there can be little doubt but that it is the oldest specimen of Grecian sculpture now existing. The architrave over this gate is of one stone, 15 feet long, and 4 feet 4 inches in height, and in it are visible sockets of about 3 inches in diameter, which received the pivots upon which the gates turned.

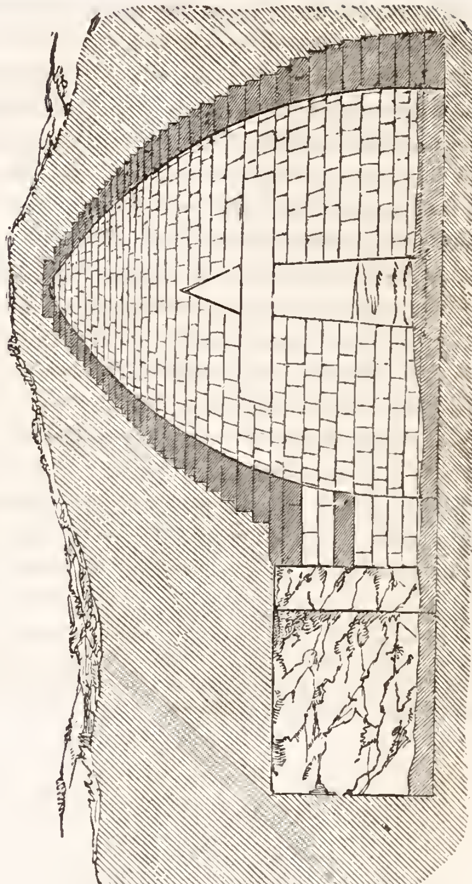
† Sir William Gell states, that on the centre of the architrave of the gates are holes, which leads him to suppose that the gates were hung from large central pivots, so that one side opened inwards, while the others advanced.

We may here mention a subterranean building at Mycenæ, known as the Treasury of Atreus, the father of Agamemnon:* the principal chamber is of a circular form, 48 feet in diameter, and about 49 feet in height. The covering of this building has the appearance of the inside of a dome, which has led some authors to suppose that the arch was known in Greece at a very early period ; but it is now ascertained that the principle of the arch does not exist in it, as the construction is the same as in the arched passages at Tiryns: the courses are horizontal, each projecting beyond the other, with the lower angles cut away until they meet at the apex, which consists of one very large stone. Beyond this is a vault or inner chamber, in the walls of which, as well as those of the larger chamber, are a number of bronze nails, which in all probability were used to fasten plate of metal to the walls ; a custom doubtless resorted to on some occasions, as we read of "brazen chambers" and "brazen temples."† The courses of stone in this build-

* Atreus came to the throne of Argos 927 B. C.

† There are other instances of subterraneous chambers being lined with thin plates of metal ; that at Argos, in which Acrisius confined his daughter, was probably similar to those of the adjacent rival city.—Vide Donaldson's 'Description of the Subterranean Chamber at Mycenæ.'

ing are regular, although of unequal size, and laid without cement: the lintel of the door is of one piece of stone, of about 27 feet long, 17 feet wide, and 3 feet 9 inches thick, and is calculated to weigh about 133 tons; a mass of stone to which none can be compared, excepting those used in Egypt.*



Notwithstanding the magnitude of these works, the science of Mechanics was in its infancy, and the

* Mr. Donaldson states that "there are numerous buildings and excavations in Egypt, Sicily, and Italy, constructed in a manner similar to this subterraneous chamber. In the Memnonium at Thebes is an oblong chamber, covered by a semi circular vaulting, the stones of which have horizontal courses projecting beyond each other as they advance in height, so as to produce that curvilinear form. Near Noto in Sicily, in the district of Falconara, on the road from Mititello to Vizzi; also in Sardinia, where these chambers are known by the name of Norages; and at Tusculum, near Rome, the same construction exists; but in none of these do we possess such correct dates as Pausanias and history itself furnish of those of Orcomenus and Mycenæ."—Vide supplementary volume to the 'Antiquities of Athens.'

Greeks bestowed but little attention on their private houses: all the splendor and magnificence of art was reserved for the embellishment of their temples and other public buildings.*

The most splendid period of the Grecian history was between the sixth and fourth centuries before the Christian era, during the time of the wars that were carried on between the Persians and the principal states of Greece, and to which the greatest prosperity of the Athenians may be attributed: literature was cultivated, and the arts of architecture and sculpture, which were employed to ornament the city, were carried to a degree of excellence that has never been surpassed. Greece was conquered by the Romans 146 B. C., and became a Roman province, although Athens and Delphi were declared as free towns. Its history from this period is without interest to us in our inquiry into the progress of art.† It was overrun by the Goths in 267 A. D., and again in 398 A. D. under Alaric; and after being occupied by the Crusaders and Venetians, at last fell into the power of the Turks, on the conquest of Constantinople.‡

CHAPTER III.

Roman Architecture.

THE Architecture of the Romans can scarcely be said to be original; it was unquestionably borrowed from the Etruscans. Etruria, a city of Italy now called Tuscany, is supposed to have been a colony of Greece. This opinion has been formed by the great solidity of the walls that surround their cities, consisting of enormous blocks of stone, similar

* One remark may not be out of place here, which will explain the mode of deciding on the date of the temples, viz., that in the earliest the diameter of the columns was greater in proportion to their height, and the intercolumniations were less, than those of a later period.

† See page 265 for further descriptions of Grecian Architecture.

‡ The cloacæ, or sewers, which extended under the whole of Rome, were a work on which time and expense were not spared; they were of wrought stone, and in height and breadth were so considerable that a cart loaded with hay could pass through them

to the masonry of the Cyclopes, and said to be coeval with the walls of Tiryns, Mycenæ, and other works of a very early age. The instruction in the art of building that the Romans received from the Etruscans was not probably before the time of the Tarquins, 540 B. C., when their edifices began to be constructed on fixed principles. The first Tarquin, who was a native of Etruria, did much towards the improvement of Rome, and brought from his native country a taste for that grandeur and solidity which prevailed in the Etruscan works. Under his reign the city was fortified, and the walls built of hewn stone. The reign of the second Tarquin was distinguised by the erection of temples, schools for both sexes, and halls for the administration of justice : this was about 508 B. C. : but to Tarquinius Superbus, the seventh and last king, Rome was indebted for its greatest improvements ; he continued the building of the temple of Jupiter Capitolinus, finished the Circus and other public buildings, and made a regular drainage of the city to the Tiber.*

It will be impossible to trace the Architecture of the Romans through its various stages between the time of the last king, 508 B. C., and the subjugation of Greece by that people in 145 B. C., a period of 363 years. The disputes in which they were continually engaged left little leisure for the arts of peace. During the time that Appius Claudius was Censor, about 309 B. C., the earliest paved road was made by the Romans ; it was first carried to Capua, and afterwards continued a length altogether of 350 miles : it was paved with the hardest stone, and it remains entire at the present day. To Appius Claudius belongs the honor of raising the first aqueduct : the water with which it supplied the city was collected from the neighborhood of Frascati, about 100 feet above the level of Rome.

The materials for carrying on a continuous investigation

* We have been compelled to go into the general history of the nations in which Architecture has originated, as it is nearly impossible to give the history of one without the other. An improvement in art has invariably been caused by some great change in the policy or religion of nations.

of the styles of the Roman buildings are so scanty, that we will not detain the reader with useless speculations, but at once proceed to that period when Greece was reduced to a Roman province, 145 B. C. Art, in the strict application of that word, was not properly understood by the victorious Romans at this time; but after a succession of triumphant wars, when immense treasure was brought to Rome, and they wished to celebrate their victories, there became a necessity for erections to record them, and the riches that were amassed were expended in the adornment of Rome.

The Greek Architects who settled in Italy executed works of great beauty; they founded a school of art, and modified that which were practised in their own country, to suit the habits, taste, and climate of the Romans. The Romans were at all times anxious to subjugate, for their own purposes, those nations that successfully cultivated the arts; a motive which, joined to the desire of aggrandizement, induced them at a very early period to carry their arms against the Etruscans, who were in a far higher state of civilization than themselves. We find that they drew supplies of artists from Sicily, Asia Minor, and Greece, instead of employing their own citizens. Although, in Rome, Architecture lost its simplicity, it gained in magnificence: it there took a deeper root than the other arts, from its affording, by the dimensions of its monuments, more splendor to the character of so dominating a nation.

The first effort of Architecture was shown in the temple reared to Minerva at Rome, by Pompey the Great, about 60 years B. C. The villas of the Romans were at this period of considerable extent: the statues of Greece had been required for their decoration, besides a plentiful supply of all that Greek art afforded. We find that Cicero was in the habit of employing two Greek architects, Chrysippus and Clautius, on his buildings.

The first permanent theatre that existed in Rome was

built by Pompey, 54 B. C., and was capable of containing 40,000 persons.

In the time of Augustus (from 30 B. C. to 14 A. D.) we find that the Italian buildings attained a point of magnificence far beyond all that preceded. The conquest of nearly the whole of the then known world, added to a general peace, allowed the sovereign to turn his thoughts to the improvement of his country; and a constellation of illustrious philosophers and poets, who shone at this time in the metropolis of the empire, gave the minds of the people an inclination towards subjects more useful and honorable than the conquest of remote and unoffending nations. The patronage of literature with the fine arts by Augustus produced the most brilliant results, and has caused a veneration for the age in which he lived. The perfection which literature and architecture attained during his dominion effected more towards immortalizing Rome than all the conquests of its emperors, and raised its inhabitants to a state of civilization never before equalled. By him was erected the temple and forum of Mars the Avenger, the theatre of Marcellus, and a large number of other public buildings. His boast was not a vain one, when he asserted that he found his capital built of brick, and he left it of marble.

Nero was the next emperor (with the exception of Claudius*) who seemed to have given his attention to Architecture; but his buildings must be considered more as monuments of his prodigality and expenditure than of correct taste. A palace was erected for him, than which nothing could be more gorgeous, nor could the pomp of decoration be carried further.

The reigns of Vespasian and Titus are justly celebrated by the erection of baths and amphitheatres of such magnitude as to astonish the world, and to which nothing of their

* During the reign of Claudius, one of the finest aqueducts of Rome was completed, whose length is 46 miles, and the water passes over arches raised more than 100 feet from the surface of the ground for nearly 10 miles of it.

kind, either before or since, will bear comparison. The Coliseum, so named from its gigantic dimensions, was commenced and finished by Vespasian and Titus: it was capable of containing 109,000 spectators, who could view the sports and combats in the arena. The baths of Titus were among the wonders of the age; but their remains are not so perfect as those of others, although they are still majestic.* The Temple of Peace, the largest covered building of antiquity, and another temple dedicated to Minerva, of the richest and most exquisite workmanship, were erected at this time, from 70 to 81 A.D.

To give a further description of the buildings of ancient Rome would be unnecessary, as our object is only to treat of the history of the Styles of Architecture, to show the periods at which they attained their greatest excellence, and to trace, as far as possible, the connection of one with the other. We therefore pass over the reigns of Trajan and Hadrian, celebrated for some fine architectural works, and proceed to the styles that sprung up, on the decline of the empire, among those nations that borrowed their first principles of art from the Romans.

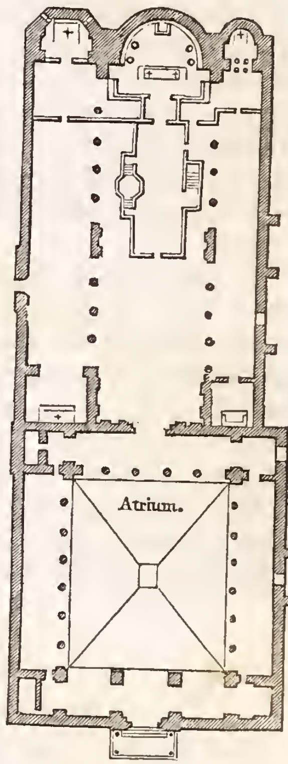
CHAPTER IV.

Byzantium and Romanesque.

From the time of Hadrian, 117 A.D., to that of Constantine, a general decline in the Arts took place, which, however, seemed to revive in the reign of the emperor, and many proofs are still extant. The churches that were built immediately after Constantine's espousal of the Christian faith. The basilicæ, or halls of justice of the ancient Romans, were undoubtedly the types from which these churches were taken; and the ruins of these buildings were often the materials used. The columns that divide the centre of the church

* The baths of Diocletian, erected 294 A. D., were of great extent and magnificence, and are in a better state of preservation than those of Titus.

were often taken from old buildings—some were reduced in height, others were mounted on pedestals to suit the purposes to which they were applied.



Among the edifices demanding notice are: the basilicia of St. Clement at Rome, said to be built on the spot occupied by St. Clement, the immediate successor of St. Peter. This is the only edifice of this style which we can describe in this work. It is entered by a court, which is surrounded by porticoes and supported by columns and piers; on the sides parallel to the front of the church arches spring from the columns, but on the others there are only architraves. Under the portico nearest the temple were placed the holy-water-vases, until in after times they were removed in the body of the church at the western door. The centre part of the atrium was then used for burial purposes. The sacristy, like all Christian churches then, was semicircular in plan, and the altar, the throne for the bishop, and exedra, or benches for the priests. It was surmounted by a half-cupola, the front of which is richly ornamented with marble and paintings of Christ and the Saints. The cupola is covered with paintings of foliage on a gold ground; the remainder of this semicircular part, known by the name of "apsis," is richly ornamented with figures of the Saints. On each side of the apsis were small apis sides. One of them was called the vestiarium, and contained the priests'

robes and the consecrated vessels; the other, the evangelium, received the sacred books, charters, &c. &c. This arrangement still exists in Greece. The chancel, which was used by the inferior ecclesiastics, and contained the pulpit and ambones, was situated in front of the apsis, and enclosed by a low partition of marble; it is raised one step from the level of the church. The floor is decorated with mosaics.

The Church of St. Sophia was consecrated May 330. It is built like a Grecian cross. It cost one million dollars. Besides this, Constantine built 25 churches. The cathedral at Pisa, in Italy, was built 700 years after that of St. Sophia. Its plan is the Latin cross. The length is 304 feet, and the width 107; the transverse branch is 234 feet by 55 feet in width. A detailed account we cannot give—a mere sketch is all we promised.

CHAPTER V.

The Architecture of Germany, France, and Normandy.

THE sacredness of religious edifices seems to have protected them from demolition and the hand of the destroyer.

Germany lays claim to churches of antiquity superior to those of any other country this side of the Alps: those existing of the tenth and eleventh centuries are very important in the history of the art, and testify extraordinary solidity and magnificence. Such are the churches of Spire, Mentz, and Worms. That of Spire was founded by Conrad, in 1030; the east end of that at Worms, still earlier, was commenced in 996, and the building was consecrated in 1016; the oldest part of the cathedral of Mentz is said to be of the date of Archbishop Willigris, between 978 and 1009.

One of the most instructive as well as the most ancient of these churches is that at Worms, now in a very perfect state of preservation. The plan is strongly distinguished by the cross; the piers separating the nave from the aisles are square,

with columns at alternate piers, to carry the stone vaulting, which embraces two compartments of the lateral arches between each groin or rib. The east end is square on the face externally, but semicircular inside; thus retaining one of the principal features of the Romanesque basilicæ. On each side are circular turrets containing staircases, and corresponding with two at the west end, although of somewhat larger dimensions. The entrances are in the north and south sides, and nearer the transepts than the west end. This arrangement is quite at variance with all preceding buildings; as instead of the three doorways at the west front, there is an apsis of the form of three sides of an octagon, which is used as a chapel. At the intersection of the nave and transepts springs an octagonal tower, which is scarcely higher than the nave roof, and covered with a cupola: the turrets are carried to a great height, and terminate conically. This church, as well as those of the same date, is vaulted with stone throughout, which caused the introduction of the shaft on the face of the piers, and is one great deviation from the arrangement of the Roman basilicæ, which were covered with horizontal ceilings; or else the wooden roofs were left exposed, which rested on the walls, having no relation vertically to the substructure.

The church of St. Castor, at Coblentz, part of which was built in the eleventh century, is likewise executed with semicircular arches, which spring from square piers, to each face of which a square column is attached. This may be considered as one of the steps leading towards the clustered columns, which gradually were introduced into the naves of all churches throughout the western part of Europe.

The early German churches, although differing considerably from each other in their general plan, still retain peculiarities that are not to be seen in those of other countries, though erected about the same period, or rather later. The octagonal form of the apsides and turrets, and their enrichments generally retaining a primitive character, made their Lombardic origin perceptible. The square piers which support the

nave arches evince a direct departure from the Italian types; there is likewise a prevalence of rectangular faces and square-edged projections. This general simplicity may be well accounted for, when we consider that the chief impressions were received from Romanesque examples, which were simplified from necessity, as there was great deficiency in knowledge of art, although no inferiority in mechanical skill.

In the cathedral of Worms we find the pointed arch, which was not introduced generally until a century after the erection of that building; therefore, if this was not added subsequently, it confutes many of the theories as to the causes and dates of its introduction.

The church of Gelnhausen, in Suabia, which was built in the beginning of the thirteenth century, is one of the earliest German churches in which a positive change of style is perceptible throughout; although in many of those of the eleventh and twelfth centuries there exists deviations from the unity of the designs which are difficult to be accounted for.

The heads of the windows, instead of being semicircular, are of the lancet form, with cusps, and differ from the proportions before adopted by being long and narrow. The arches and windows in the nave have trefoiled heads, and the windows of the central tower possess a marked distinction from the earlier arrangements, having the three apertures with trefoils inscribed in a semicircular top, and separated by mullions.

The church of St. Catherine at Oppenheim, commenced in 1262, resembles in plan that of Worms, being in the form of a Latin cross, and having semi-octagonal chancels at the east and west ends. The latter is of a subsequent date, and was not consecrated before 1439. This peculiarity is observable in several other churches in Germany: the entrances are on the north and south sides.

The cathedral of Strasburg, which was begun in 1227, and brought to its present state in 1439, holds the first rank among the Gothic churches of the Continent, in point

of the high degree of enrichment which prevails throughout The length of the body of the church is 324 feet, and the height of the nave vault is 98 feet. The western facade is divided into three parts, vertically, by buttresses richly ornamented with canopies and statues. The three entrances are crowned by crocketed gables, and the diverging sides of the doorways are completely filled with niches and statues.

This cathedral has but one of its spires completed, which is at the north-west angle: it is perforated in the richest manner, and in height it exceeds any other church in Europe, being 414 feet from the ground.

The cathedral of Cologne was one of magnificent design, and of a symmetry not surpassed by any of the best works of Greece or Rome. The site was the ruins of a church built by Charlemagne. Archbishop Conrad commenced the church in 1249. The length was over 500 feet; the width of the aisles 180 feet; the roofs more than 200 feet high. The western towers were to be 500 feet high, and 100 feet wide at the base. For three centuries the work, by spasmodic efforts, was extended; but the building was never entirely completed. All that is now done is to keep it in repair.

The German cathedral at Ulm was commenced in 1377. Its length is 416; width, 166; height, 141.

Ratisbone cathedral was built in 1480.

The greatest variety of forms, both in traceries and ornaments, prevails throughout most of the larger churches of Germany that were built in the latter part of the Gothic era.

The buildings of France of the ninth and tenth centuries were like those of Germany, in the Byzantine or Romanesque styles, and decorated with a profusion of mosaic and other ornamental work.

The invasion of the Normans, in the ninth and tenth centuries, caused the destruction of most of the ecclesiastical edifices. After Rollo had become Duke of Normandy, and

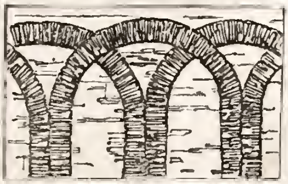
embraced the Christian faith, he vied with France in the erection of churches. The principles of the architecture that prevailed in both countries were identical, being modifications of the Lombardic styles, and were characterized by the general use of the semi-circular forms in arches or windows.

One of the earliest French churches that presents any features that require our notice, is that of St. Germain des Pres, which was built by Abbot Morard, in 1014. The nave of the church still remains in its primitive state. The capitals of the columns possess much of the character of the Corinthian Order; whilst others are composed of birds and griffins. In the churches of Normandy, the capitals of the columns are direct imitations of the Corinthian Order, with the exception of the abaci.

About 800 years ago the large cathedral of Chartres and the abbey of Cluny of France were built. The plan is cruciform.

Towards the end of the twelfth century an important change took place in the architecture of the western parts of Europe, by the introduction of the pointed arch, which was used instead of the semicircular.

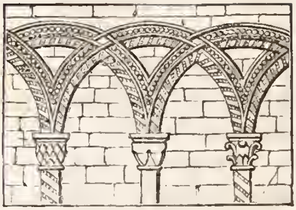
Concerning the origin of the pointed arch we cannot treat. By some it is supposed that it was used in Noah's Ark—and some buildings of great antiquity in the east, at Jerusalem and Cairo, are of a pointed form.



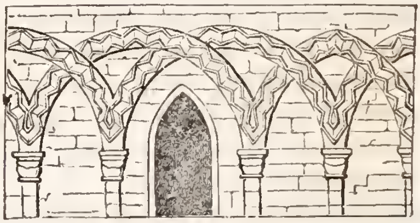
Dr. Milner supposes that it arose from the intersection of semicircular arches, which were frequently introduced on the surface of the walls in the Norman Styles, but placed there solely for ornament, as in St.Botolph's, Colchester, (England.)

At Castle Acre Priory the transition is apparent; and at Bristol Cathedral it is still further developed.

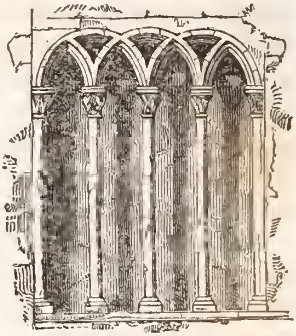
Castle Acre Priory.



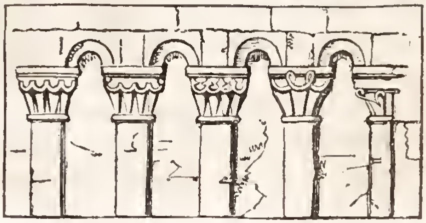
Bristol Cathedral.



At St. James's, Bristol, within the interlacing mouldings, there is a lancet window, the arch of which is struck from the same centres, and follows the inside lines. In the above instances referred to, the intersecting semicircular windows are not detached from the wall.



In Christ Church, Oxford, erected 1180, there is an instance of an interlacing arcade supported by columns entirely disengaged from the wall, and from its construction as well as its form may be considered as a transition between the semicircular and the pointed styles.



The pointed form suggests a greater loftiness and elegance in eomposition, and to a certain extent the principles of arrangement are different: these again, in their turn, gradually gave plaee to others, apparently as mueh at varianee with them as they were from the parent souree.

The Editor differs from his Author and agrees with Sir Christopher Wren, that the Saraeens of the East, or the Moors of Spain were the originators of the pointed style of Architecture.

CHAPTER VI.

Syrian, Persian, and Persepolitan Architecture.

The aneient edifiees of Syria were undoubtedly of a eharaeter very similar to the Egyptians, if we may judge from the intereourse that existed between these nations. There are no monuments left us of Phœnieian arehiteeture.

Solomon's Temple was built by an arehiteet and workmen from Tyre. The plan was a paralellogram of about 109½ feet by 36 feet; in front was a pronaos or portieo extending along the whole width of the temple, the depth of whieh was half its extent. The eell or main body of the building was 54¾ feet deep, and the sanetuary beyond 36½. The height of the sanetuary was 36½ feet, the middle part or eell 54¾, and the portieo 36½. The body temple was surrounded by three tiers of Chambers, to whieh there was an aseent by stairs, and the eentral spaee was a eourt open to the sky. Bells were suspended about the temple and were probably intended by the sound they produeed on being agitated by the wind, to keep off the birds from the eonseerated edifiee. The ends of the beams of the upper floors rested on stone eorbels, and were not inserted into the walls, whieh were lined with eedar, on whieh were figures of eherubim made of wood and eovered with gold; these were ten cubits high, and their expanded wings extended across the

width of the temple. In front of the portico were two pillars of brass, each five cubits high, and nearly four cubits in diameter. The chapiters or capitals, also of brass, were five cubits high; one was ornamented with lilies on a net-work ground, the other with pomegranates.

The "House of the Forest of Lebanon" was larger still than the temple.

Persia was the seat of one of the most powerful empires of Asia from a very early period until the invasion of the country by Alexander the Great, 330 B.C., during which time the art of building must have been practised to a great extent. But alas! "time the destroyer" has left nothing but ruins from which we may judge of its former splendor. On the great fertile plain of Merdasht or Istaker, in the province of Farisistan, are the ruins of the city of Persepolis. The ruins are 1,200 feet from north to south, and 600 feet from east to west. It is undoubtedly the site of a palace. There are other ruins, and all seem to indicate that some intimate connection must have existed between the architects of Persia and Egypt.

A great resemblance exists between the present architecture of Persia and other Mahommedan countries, and it therefore requires no description of its peculiarities.

CHAPTER VII.

The Ancient Architecture of India.

Of all the remains of ancient buildings that have attracted the curiosity or attention of the traveller devoted to antiquarian research, none have been investigated with less satisfaction as regards their history or chronology than those of India.

The ancient monuments of India are of two kinds, the excavated and the structural; the one being cut out of the rocks, while the others are erected of different materials in

the usual way. The former were made by the Buddhists, a sect whose earliest existence dates 600 B.C.

The caves consist of three classes: the first of these are Vihara, or monastery caves, the earliest of which are natural caverns slightly improved by art, appropriated to religious purposes: those which followed had a verandah opening into the cells for the abodes of the priests, but without sanctuaries or images of any kind. The simplest form of these consists of merely one square cell and a porch, sometimes nearly 30 feet in length; in others the arrangement is extended by the verandah opening into a square hall, on three sides of which the cells are placed. Another subdivision of the Vihara caves consists in the enlargement of the hall and the conseqûent necessity for the use of pillars. In these, besides the cells there was always a deep recess facing the entrance, in which the statue of Buddah, with his attendants, was usually placed; thus making the cave not only an abode for the priests, but a place of worship. To this division by far the greater number of Buddhist excavations belong; those at Ajunta are the finest, though good specimens exist at Ellora and Salsette.

The second class consists of Buddhist Chaitya caves: these must be considered as the temples or churches, and one or more of them is attached to every set of caves in the west of India: the plan and arrangement of them are exactly the same, though the details and sculpture vary with the age in which they were erected. These, unlike the Viharas, seem to have taken the same form at once, as is seen in that of Karli, which is the most perfect, and believed to be the oldest in India. It has been supposed from this circumstance that they were copies of the interiors of structural buildings, though no traces of such buildings exist in India, Ceylon, or beyond the Ganges. In all these caves there is an external porch, or music-gallery, and an internal gallery over the entrance; the centre part of the temple is surrounded by circular or octagonal pillars that divide it from the aisles, and

are carried round the semicircular part at the farthest end, and which may be considered as an apsis: the whole bears a strong resemblance to the arrangement of the early Norman churches. The nave or centre part is twice its width, and is roofed by a wagon vault; the roof of the aisles is generally flat. In the centre of the semicircular part stands the Daghopa, in part of which there is always a sculptured niche containing a figure of Buddha and his attendants. The third class consists of Brahmanical caves, many of which have a great resemblance to the Vihara, though the arrangement of the pillars and the position of the sanctuary are in no instance the same. The walls are nearly always covered with sculpture, while the Viharas are generally decorated with painting and inscriptions. The finest specimens are at Elephanta and Ellora; others are to be found in the island of Salsette, near Bombay. The excavated temple at Elephanta is 130 feet long by 110 feet wide, and 14½ in height. The ceiling is flat and supported by four rows of columns connected by a fascia, or simple architrave: the columns are 9 feet high, standing on pedestals; they are reeded or ribbed, and have projecting capitals of a semicircular form in profile, from which spring the brackets of the ceiling. Against the walls are sculptured colossal human figures in high relief, which differ from each other by a variety of symbols, representing the attributes of the deities whom they worshipped. At the farthest end there is a square recess, supposed to be the sanctuary; on either side of the door by which it is entered there are large figures. There are 100 of these caves three stories high cut out of the rock. Some are 150 feet high. The Buddhists nearly always adopted the Arch form in their Chaitya temples.

There is still another class of excavations cut out of rock; they are of one block of stone. These temples have the appearance of standing in pits, as all the surrounding parts have been cut away. The most remarkable of this class is the Kylas aud Ellora, which is one of the most modern spe-

cimens of excavations in India, built about 900 A.D. It is 400 feet long by 247 wide, and is at the north-east angle 104 feet deep; round the sides of this area is a cloister supported on square pillars, which are covered with subjects from the Indian mythology. The centre part is occupied with the entrance pavilion, the chapel of Nandi and the grand temple and sanctuary, round which are balconies supposed to have been used by the musicians on solemn occasions. The approach to it is by a bridge, from which you descend to the chapel by nine steps; and, on passing on over another bridge, you arrive at staircases on either side, which lead to the inner court, the temple and cloisters. On each side of the bridge are gigantic representations of elephants, and beyond are two richly carved pillars or obelisks.

The upper parts of the buildings were supported on square piers or pillars, and from all sides of their capitals brackets projected equal to their width, and leaving generally a space equal to three diameters between their greatest projection, thus leaving only one-half of the whole length of the architrave unsupported; but when a greater space was required, a succession of projecting brackets placed above each other was adopted, sometimes meeting in the centre, thus having the effect of a horizontal arch. The effect of this is undoubtedly pleasing, as the projecting brackets on all sides of the square capital produce in perspective a variety of lines, and great play of light and shade.

One of the oldest structural monuments or temples is that of Bobaneswar, which is 60 feet square at the base and 180 feet in height.

In plan the Indian temples or pagodas are square; the only light that is admitted is by the door.

One of the largest Hindoo temples is that at Chillambaram, on the Coromandel coast, which from its dimensions and antiquity is held in high veneration. This cluster of temples is a rectangular space 1332 feet in length by 936 in width, by walls 30 feet in height. This area contains a

variety of temples, much decorated with sculpture of figures and ornaments more curious than beautiful; these are connected by extensive colonnades and porticoes. Pyramids stand over the entrance of the outer enclosures, and consist of several floors.

There are many other pagodas of large dimensions.

Among the interesting works of the Hindoos are the Bunds or dams, which are made for the purpose of intercepting the course of small rivers, so as to form an artificial lake for the purpose of irrigation: on these dams, which are constructed of stone, palaces and temples are generally placed, and between them are very broad flights of steps leading down to the water, which are ornamented frequently with figures of elephants, and were used as fountains. That at Raj-Sing, at Oddypore, is 386 paces in length, and was built in 1653.

The Indian styles, whatever their defects may be, have the merit of being original; for there can be little doubt but that they were invented in the country where we now find them.

CHAPTER VIII.

Chinese Architecture.

The architecture of China, unlike that of other nations, has retained its particular character during all times without any mutation. Their native historians ascribe the origin of building to their Emperor Fou-Hi, who first taught his subjects that art about 368 B.C. In the year 246 A.D., the Emperor Tsin-Chi-Hoang-Ti demolished all the buildings of importance, so as to remove all records of the grandeur and power of his predecessors: except a few temples and tombs in the mountains, which are supposed to be of a prior date, nothing remains of a higher antiquity.

The type of all Chinese buildings, whether they are used

for the purposes of religion, or as residences, is undoubtedly a tent; and the convex form of their roofs shows that they are a copy of those made of more pliant materials, sustained at different points from brackets at the top of vertical supports. The material generally employed is wood; that most in use is the nan-mon, which is said to last more than a thousand years: stone, marble, bricks, bamboo, and porcelain tiles, are also used.

In China, improvement seems to have been considered an innovation and direct breach of the laws, which are looked upon as something more than human ordinances, from their supposed perfection and antiquity.

One great hindrance to any advance in architecture is caused by the construction of their private houses and public buildings being subject to the restrictions of public functionaries (who may be properly designated district surveyors), backed by most arbitrary laws: under their supervision every one is obliged to build according to his rank, and for every house a certain size as well as details are fixed. These officers seem to govern the arts in China, and the laws regulate the magnitude and arrangement of residences of the various degrees,—for a noble family, for a president of a tribune, for a mandarin, and for all classes who can afford the luxury of a house. The size of public buildings likewise comes under their management. The merchant, whatever the amount of his wealth may be, is compelled by this regulation to restrict the dimensions and decorations of his house to his exact grade or standing: this refers only to the external part of his dwelling; the interior arrangements are unfettered. According to these prohibitions (for they cannot be considered in any other light), the level of the ground floor, the length of the frontage of the building, and the height of the roofs, are in an advancing scale from the citizen to the emperor, and their limits must be attended to without appeal.

The buildings generally are only of one story; and in Pekin

the shopkeepers are obliged to sleep under their pent-houses in the open air in summer. One reason perhaps justifies their houses generally being only of one story, which is the slightness of their construction, and which renders them incapable of bearing any thing above them. The general character and arrangement of the Chinese houses is so well understood, that no object will be gained by enlarging on the subject. In every part, nothing is seen but a succession of combinations of frame-work and trellises painted in all the primitive colors, which has caused the impression that the Chinese houses bear a greater affinity to bird-cages than to any thing under the sun : the form of some of their doors is sometimes circular or octagonal, and tends to strengthen it, as in no other country are apertures of that form used for entrances.

The palaces resemble a number of tents united ; and the highest pagodas are nothing else than a succession of them piled on one another, instead of side by side : in short, from the smallest village to the imperial residence at Pekin, no other form but that of a permanent encampment prevails. Lord Macartney, who travelled the whole empire from the farthest part of the great wall to Canton, observed that there was but very little variation in the buildings to be seen.

Amidst the substantial works of the Chinese the most remarkable are the bridges : that at Loyau, in the province of Fod-Kien, is composed of 250 piers built with very large stones, which support enormous granite lintels, or stones placed horizontally ; these are crowned by a balustrade. A considerable number of bridges have been constructed in China, and they are considered to be works of great magnitude and importance. To the Chinese is attributed the earliest application of the suspension bridge, which has been so much adopted in modern times in situations where no other means of passage could have been applied.

The temples of the Chinese are generally small, and consist of only one chamber, which is the sanctuary of their

idols ; on the outside is a gallery : others stand in a court surrounded by corridors. In some instances the interior is spacious : that at Ho-Nang, near Canton, is 590 feet in length by 250 in width ; the temple is constructed of wood, and covered with painted and varnished porcelain. It has been estimated that Pekin and its environs contain nearly 10,000 mido or idol temples, some of which are superior in decoration to those at Canton.

Amongst the buildings that are peculiar to China are the pagodas, or towers of from six to ten stories, diminishing upwards : the projecting top of each story presents the concave form before referred to ; and the plan of those buildings is generally an octagon. The most celebrated is that of Nang-King, which is called "the tower of porcelain ;" it is 40 feet in diameter at the base and 200 feet in height ; in the centre is a staircase connecting each stage, and which is lighted by windows on four sides ; the openings do not occur over each other, but in alternate stories ; the whole is cased with porcelain. The age of this pagoda is little more than three centuries.

Commemorative buildings and triumphal arches or doors are very numerous throughout China : they are placed at the entrances of streets as well as before principal buildings ; the better class of which consist of a central and two side openings : the lower part is generally of stone, without any mouldings ; the upper part is of wood, and supported on horizontal lintels, the constructive arch being as little known in China as in other Eastern nations.

The great wall, which extends for 1500 miles, has perhaps caused a much higher opinion to be formed of the monuments of the Chinese than a careful survey justifies. It is (with an exception in favor of their bridges) the only work of any importance that can give the Chinese any position as a constructive people.* It consists of an earthen mound faced by

* From the architecture as well as the ornamental works, the impression is conveyed that mechanical skill and imitation are the only faculties that are possessed

walls of brick and masonry ; its total height is 20 feet. The platform on the top is 15 feet broad, and increases to 25 feet at the base of the wall ; at intervals of 200 paces are towers of 40 feet square, which diminish to 30 feet at the top ; their height in some places is 37 feet, in others 48. This wall, which commences in the sea to the east of Pekin, extends along the frontiers of their provinces, over rivers, mountains, villages, and often in places that are of themselves protections from any hostile invasion : it engaged a million of persons for ten years in its erection.*

CHAPTER IX.

Arabian, Saracenic, or Moorish Architecture.

In consequence of the very few examples remaining, we have little evidence of the ancient architecture of the Arabians. The Caaba at Mecca is the only existing temple in which the Arabians worshiped their idols : this was so much altered by Mahommed, that it is difficult to trace the portions of the prior erections.

From the appearance of Mahommed, A.D. 600, commenced a style of architecture which extended from the Indus along the northern coasts of Africa, and to a considerable portion

by the Chinese, as their arts seem to be confined to servile copies of the works of Nature, without any feeling of composition or invention. The ancient people must indeed have been widely different in their composition, as they have credit for the discovery of the magnetic compass before 121 A. D. ; the art of printing in the tenth century ; the earliest manufacture of silk and poreclain ; and last, though not least, the composition of gunpowder, which their descendants of the present day use to so little purpose.

* The first emperor of the Tsin dynasty caused this wall to be built as a protection against the Tartars, though it has been supposed that the employment of a large mass of people, who were in a state of excitement at his tyranny, was the more direct cause of its erection, or it would not have been carried over places that were quite inaccessible to an enemy, and therefore in these situations useless. It has now stood nearly sixteen hundred years. He ordered all the books of the learned, including the writings of Confucius, to be cast into the flames, for the same reason that caused the destruction of all the principal existing buildings.

of Spain. In the latter country it attained its greatest excellence.

The mosque which was built at Jerusalem by Omar, the second caliph, about A.D. 640, is supposed to have been the first of their erections beyond the limits of Arabia. Of the nature of this edifice we are ignorant, in consequence of the numerous additions made to it at subsequent periods. When Damascus became the seat of the empire, it was considerably improved; and among its splendid buildings was the celebrated mosque founded by Alwalid II. In the year A. D. 762, the foundations of Bagdad were laid; and this city remained the imperial seat for 500 years. The magnificence of the palace of the caliphs could only be exceeded by that of the Persian kings; and the pious and charitable works of those days have never been equalled, as water cisterns and caravanseras were built along several hundred miles of road.

Nearly all the remains of the ancient architecture of the Eastern Saracens are the mosques at Mecca and Jerusalem: to these may be added the castle of Cairo, and the ruins of the hall of Joseph.

The most splendid specimens of Arabian or Saracenic architecture are to be found in Spain, of which the most ancient is the mosque at Cordova, begun in 780 by Abd-el-rahman, then king of this part of the Moorish dominious. It was erected within the first century after the Moors had established themselves in Spain.* It is an insulated parallelogram of 620 feet in length by 420 in breadth, and is divided into two parts; one of them is an open court, in which worshipers performed their ablutions before entering into the body of the temple: on three sides there is a colonnade 25 feet wide, and on the other are the several doors

* The Moors, under Musa Ibn Nosseyr, the viceroy of the northern part of Africa, landed in the south of Spain A.D. 711, A. H. 89; and within two months, Cordova, Granada, Jaen, Malaga, and Toledo, then the capital of Spain, were reduced, or opened their gates to the conquerors. The mosque of Cordova was finished by Hisham, A.D. 794.

communicating with the mosque. This consists of nineteen naves divided by seventeen rows of columns: thus the interior presents an appearance of a forest of columns composed of jasper and other marbles; they are 18 inches in diameter, and surmounted by capitals which bear a strong resemblance to the Corinthian and composite orders;* these are connected by segmental arches. The ceilings are of wood, painted; the enrichments are of stucco, also painted in various colors, decorated with legends and occasionally gilt. After the conquest of the city by San Ferdinand, in 1238, the mosque was converted into a cathedral; and the character has since been greatly injured by erections that were necessary for its adaptation to the service of the Christian religion.

The most perfect example existing, that can convey an idea of the extent to which sumptuousness of ornament and enrichment can be carried, is to be found in the Alhambra, the residence of the Moorish kings of Granada, erected between the years A. D. 1240 and 1348. In this there are no traces of art peculiar to any other nation; the composition and distribution of the ornaments being arranged with consummate skill. To attempt a short description of this model of pure Arabian architecture would only be an injustice to it, as no notion would thereby be conveyed of this extraordinary work; we therefore can only remark, that every part of the walls and ceilings is covered with a mass of ornament enriched with gold and the most brilliant colors, and which bears the strongest evidence of the high degree of refinement and luxury at which the Moors had arrived prior to their overthrow.† The whole of the ornaments are composed of

* These were probably obtained from some Roman buildings that existed in the neighbourhood, as some of them have bases, so as to bring them to the required height, while others, which were too short, were lengthened by giving them tall capitals. In this building there are upwards of 900 columns.

† For a full description, with views and the details represented in their original colors, the reader is referred to the work published by Mr. Owen Jones, which is truly worthy of the magnificence that it illustrates; and it is to be regretted that it has not received sufficient patronage to reimburse him. His principal remuneration must be the conviction that he has produced that which is unequalled in execution by any thing that has preceded it.

stucco; and it has been observed, that no nation has constructed so many magnificent buildings without having recourse to the quarry.

Moorish architecture has several kinds of arches: the horse-shoe form, having the centre raised above the spring of the curve, which likewise diminishes in width; the pointed arch, in which, likewise, the greatest width is above the impost or spring from which the curve commences. Some of these arches contain on the inside a succession of small cusps of a segmental form. The next example is that of the cuspid arch, strictly so termed, the outline being produced by intersecting semicircles, very similar to the trefoil heads of Gothic windows, with the exception that they are not circumscribed by a continuous arch. Another example in the Court of Lions in the Alhambra, it being circle headed and stilted and considerably more than a semicircle: the part below the centre of the curve is vertical, and rests on small corbels that are fixed against panels wider than the slender pillars that support them.

The style is noted for its extremely slender proportions and for its fanciful and diverse character.

Among the features of this style is the honeycomb, fretwork, or pendants, which compose the ceilings of the buildings of the later dates. It is a cone-shaped covering, but ornated with a multiplicity of projecting forms, which render its appearance at first perplexing; but, like the mosaics, it is extremely simple in principle.

CHAPTER X.

Druidical, Celtic, and Anglo-Roman Architecture.

The earliest remains of a structural nature are the unhewn stones which, in various forms, are found in different parts of the island. The introduction of those in the southern parts are chiefly attributed to the Phœnicians, or Ca-

naanites of Tyre and Sidon, who were the most expert sailors of antiquity, and maintained a commerce with the southern parts of England.

It is quite certain that their frequent voyages suggested the idea of planting a colony in this part of Britain, and that they then introduced the custom of erecting gigantic stones, which had been practised in Asia. These erections are varied, and may be classed as follows: 1, the single stone or obelisk; 2, circles of stones of different numbers; 3, sacrificial stones; 4, cromlechs and cairns; 5, logan stones; 6, tolmen, or colossal stones.

The most remarkable of these monuments is on Salisbury Plain, in Wiltshire, which has been generally considered as a Druidical or Celtic work. It consists of concentric circles of large stones, placed upright in the ground like pillars, with another large stone resting upon them as an architrave or lintel, which is secured by mortices and tenons; thus indicating a regular principle of construction, although the stones themselves are not squared.

The earliest habitations of the Britons were of a circular form, and composed of wicker filled in with clay, and sometimes placed upon foundations of stone; although caves were much used at the same time.

The erection of solid buildings in England dates from the invasion of Julius Cæsar, in the year 55 B. C. Quite an impetus was given to the building propensities of the people, and in the third century Britain was noted for the number and skill of its artificers. After the departure of the Romans, A. D. 410, architecture declined.

CHAPTER X.

Architecture in England,

The History of Agriculture in England commences with structures of unhewn stone, the remains of which, in various forms, are found in different parts of the island. Their in-

troduction is chiefly attributed to the Phœnicians or Canaanites of Tyre and Sidon, who were expert sailors and maintained a commerce with the southern parts of England.

The most remarkable of their monuments is Stonehenge, on Salisbury Plain, in Wiltshire. It consists of concentric circles of large stones, placed upright in the ground like pillars, with another large stone resting upon them as an architrave or lintel, which is secured by mortices and tenons; thus indicating a regular principle of construction, although the stones themselves are not squared. The remains at Arebury, near Silsbury Hill, are merely rude masses of stone work in the form of a circle, with smaller detached circles of unhewn stones within its other area.

The earliest habitations of the Britons were of a circular form, and composed of wicker filled in with clay, and sometimes placed upon foundations of stone.

From the invasion of Julius Cæsar, in the year 55 B. C., may be dated the erection of solid buildings—temples, theatres and public edifices were erected, and the art of architecture advanced till the departure of the Romans in 410 A. D. This is the "Druidical, Celtic, and Anglo-Roman Architecture" of England.

The "Anglo-Saxon" Architecture commenced with the arrival of the Saxons in 449 A. D. What little remained of the art was shortly extinguished, for the Saxons, like the inhabitants of the other parts of Germany, were totally ignorant of all civilized modes of living, being accustomed to dwell only in hovels, built in the rudest manner with branches of trees and reeds; all knowledge of building, therefore, seems to have been lost for nearly two centuries afterwards.

In the latter part of the 7th century the art of building stone edifices was revived, and many churches were built "after the Roman manner," or debased Roman style then prevalent in France and Germany. This style has received the title of Anglo-Saxon. The plans of the churches dif-

fered considerably, and must have been regulated by their size. Some were cruciform—in fact a goodly portion were. The builders used to construct crypts beneath their most celebrated churches. The plans of the smaller churches were generally oblong. The towers were usually placed at the west end. The quoins are of a description known as the Anglo-Saxon style, and called long and short work, from their being arranged with stones of equal size, placed alternately in a vertical and horizontal position upon each other, thus bearing resemblance to debased rustic work.

The heads of the doorway of the Anglo-Saxon style are either triangular or semicircular; the latter were more generally used, and those which are more ancient were constructed of large flat bricks or tiles placed on end, and the spaces between, which are nearly equal to them in width, filled in with coarse rubble-work; the jambs or imposts of the arches were generally of stone. The mode of forming these arches, as well as the walls in which tiles were introduced, either in horizontal layers, or arranged herring-bone fashion, was undoubtedly copied from the later works of the Romans.

The triangular-arched head is of a later date, and possesses little constructive merit; the extreme of the triangle rests on a plain abacus, the impost in some cases projecting from the wall. The prevailing character of the Anglo-Saxon style is massiveness, with only the occasional introduction of a moulding, which in most cases consists simply of a square-faced projection with a chamfer or splay on the upper or lower edge; the sculpture of that period was extremely rude, and rarely introduced.

The principal religious edifices were destroyed on the subjugation of the country by the Danes, 1012 A. D.

The commencement of the "*Anglo-Norman Style*" is dated from the Conquest by William, in 1066 A. D. Churches were built so rapidly that 70 years afterwards, on the compilation

of the Doomsday Book, 1700 were recorded as then being in existence.

The Anglo-Norman conventual churches were cruciform in plan, with a low tower rising at the intersection of the choir and nave with the transepts: the former, as in the case of some churches in Germany, terminated with a semicircular apse. Apsidal eastern terminations were frequently appended to the chapels attached to the churches. The aisles were continuous throughout the choir as well as the nave, so that on solemn occasions the whole church might be traversed in processions. The altar was generally affixed to a low reredos screen or wall, which was placed between the easternmost piers. Above the aisles that extended round the nave and choir was a triform which communicated with chapels similar to those below. The west or principal front was sometimes flanked with towers, in addition to that before named; at the angles of the transepts and porches were generally placed massive buttresses, or else turrets terminated by conical or polygonical-shaped cappings or pinnacles. In the smaller churches, the plans were similar to those of the Anglo-Saxons, and consisted only of a nave and chancel, with a low square tower at the junction, supported by bold semicircular arches: in these the apse at the east end is very frequently introduced; indeed it is a distinctive feature of that style which bears the name of Norman or Romanesque (derived from ancient basilicæ), and never introduced after the style which we immediately received from the Continent, namely, the semicircular-arched, had passed away.

The Anglo-Norman style of architecture might be divided into three classes,—the Primitive, the Enriched, and the Transition: in the two former kinds, the principles are identical, although the mode of ornamentation that is used, unless considered in its various stages, appears to be the result of fresh impressions derived from some foreign source: as regards the latter, it explains itself, having features of a

somewhat different character, which were the germs of a style totally dissimilar in principle.

The Norman style embraces the very plainest as well as the richest specimens of work, from that characterized by the low square and circular piers, so numerously distributed about the country, to the florid decoration with which many of our cathedrals and abbeys are embellished. The former of these exhibit but massive and clumsy remains of the classical principles, but they display a grandeur and solemnity of appearance from the solidity of masonry and smallness of the openings. The piers in the earlier buildings were either entirely square, or else a succession of receding faces crowned by a plain square abacus, the lower edge of which was chamfered. Isolated circular columns were likewise used in this country shortly after the Conquest, as at the chapel of the White Tower, London, Great Malvern church, and the cathedrals of Gloucester, Peterborough, Durham, and Hereford,* besides several conventual and collegiate churches. At the later periods, portions of columns were attached to the square piers ; those facing the nave or choir were carried up to the clerestory windows, and from their capitals sprung the ribs of the groining of the roof ; the others carried a part of the mouldings of the nave arches, as in Norwich and Peterborough cathedrals. In the latest instances, the square pier is entirely discontinued, and the columns are connected together without the angular pieces.

The arrangement of the interior compartments of the Norman cathedrals and larger churches is that from which nearly all others of subsequent dates were copied; it consisted of three tiers or stages. The lower or larger opening was spanned by a simicircular arch, which rested on the piers before described, above which was a horizontal string-course : in the second story, or triforium, were two smaller arches, supported in the centre by a slender column ; these were

* Fifteen of the twenty-two English cathedrals retain parts of their Norman erection, either in the crypts or superstructure.

enclosed in a larger aich, the span of which was rather less than that below it ; above this was another string-course : in the third, or clerestory, there were generally three arched openings divided by columns, that in the centre being higher and wider than the others, and forming either the window, or an opening before it, in the thickness of the wall. These three arches generally occupied a space equal to the arch below them, and were enclosed in the arch springing from the shaft which formed part of the semi-circular stone groining with which the larger churches were usually vaulted.

In all the Anglo-Norman Churches, the western and southern doorway seems to have been decorated with a profusion of ornamental mouldings and sculpture. Many of the Norman doorways have the arch heads filled up, forming what is called the tympanum ; this is frequently adorned by sculpture of the Savior, angels, saints or animals.

Another peculiarity of this style is, that the arch is the feature on which the greatest amount of ornament and enrichment was bestowed. The decorative details and moulding of this style, although numerous are of a peculiar description, and appear to have been worked on the originally plain surface of the masonary, and, in many cases, re-worked at an after period to a greater degree of richness than they originally possessed. The chevron or zig-zag, for instance is the most common ; in the earlier instances its form is little more than indented on the plain face of the projection or wall ; afterwards we find it partially beaded ; then double beaded with hollow ; and in the latest examples it was completely cut away, and standing out in full relief, with a second series of mouldings carved on the backing. There is also the billet—the pellet,—the star—the nail-head—and the embattled fretted mouldings.

The windows of this style were usually small and extremely simple, having no mouldings round them, but only a receding face on the outside, the inside being splayed. Towards the beginning of the twelfth century, mouldings and columns

were introduced in the jambs, and the semi-circular heads were carved with the zig-zag and other enrichments ; about the year 1180 the highest degree of ornamentation ever applied to Norman art was arrived at.

The Norman style, which had been gradually advancing, in the richness of its arrangement and ornaments, from the period of its introduction into this country up to the middle of the twelfth century, began from that time to evince the germs of different combinations and features, which were characterized by the verticality of its principles, and a change from the semi-circular to the pointed form of the arch. This has been called the Transition, or Semi-Norman style, as in it we find the pointed arch in its incipient state, formed by the intersections of portions of a circle, whilst the details and accessories remained unaltered : thus was the pointed arch, for nearly fifty years, completely intermixed, more or less, in conjunction with the pure Norman style, without entirely superseding it, until the close of the twelfth century. We have already drawn the attention of our readers to some of the various theories respecting the direct origin of the pointed arch, and shall therefore offer no further observations on them, but merely consider this prominent feature as we find it introduced in our buildings, apparently resulting from new combinations, and as being the consequence, and not the cause, of a new style.

The Transition, or Semi-Norman style, which lasted during the reigns of Henry the Second and Richard the First, evinced, in its early stages, no other deviation from the Norman than that of the arches being pointed ; but these were frequently introduced in situations where the old form was actually built with and even surmounting them. Thus we find them in the choir of the church of St. Cross Hampshire : the lower arches here are pointed, whilst the arcade above, as well as the clerestory, is strictly Norman : the same arrangement exists at Malmsbury abbey church, with the exception of the upper story having been built nearly two

THE PARTHENON

page 258.

centuries afterwards. In the transept of Romsey church, at the west end of Croyland abbey church, Lincolnshire, and in many other instances, the pointed arch is placed beneath the semi-circular; and this has not been an after alteration, but is really the original work. The span of the arches at this time became greater, the columns higher and less massive, and the capitals began to be ornamented with a kind of foliage terminating in a volute or bulbous leaf.* The columns were frequently octagonal in form, and the bases had additional mouldings with an overlaping ornament at the angles, and were placed upon square plinths.

Although the alteration of the arch and diminution in the massiveness of the columns were at first the only indications of a transition from the style of the Normans, yet other peculiarities, which followed in gradual succession, bear testimony to the certain progress that was being made towards a more ornate and lighter style of architecture. The mouldings were more generally beaded and less massive, yet the use of the zig-zag, of various forms, was still retained. The columns of the doorways were frequently banded in the centre, and placed quite free in the receding angles and splays.

Examples of this period may be instanced in many of the Norman, as well as Early Pointed buildings: the great west tower and south wing of Ely cathedral are especially deserving of attention. Perhaps no finer specimen than this exists in the kingdom: the pointed arch, the trefoiled head, and other features of the next period in this example, here just begin to appear, although the whole aspect is decidedly Norman. The vastness of the surfaces, which are completely covered by arcading and sculpture, both within and without, from the ground to the very roofs, is almost bewildering to the eye: the date is about 1170.† Buildwas abbey, Shropshire; Malmsbury, Kirkstall, Fountains, and Croyland abbeys; the churches of New Shoreham; Rutland, North-

* The eastern part of Canterbury cathedral illustrates these peculiarities.

† Paley's 'Manual of Gothic,' p. 68.

amptonshire ; Walsoken, Norfolk ; Ketton, Rutland; Bloxham, Oxfordshire ; Little Snoring, Norfolk ; retain portions of the work of this date. Trinity chapel, and the circular part called Becket's Crown, Canterbury cathedral, built A. D. 1175, are very interesting : St. Joseph's chapel, Glastonbury, erected at this period, is perhaps the richest specimen now remaining of the Semi-Norman, or Transition style, and remarkable for the profusion and beauty of its sculptured detail, as well as the close resemblance it presents in many parts to the succeeding styles.*

It has been usual to date the introduction of the Pointed, or what has been denominated the Early English style,† to about A. D. 1200, although the vertical principles from which it sprung were not fully developed for thirty years afterwards. The lancet, as well as the equilateral shaped arch, were used at this period. The mouldings in general consist of alternate rounds and deep cut-hollows, producing a strong effect of light and shade : the tooth ornament is of frequent occurrence and used only in architecture at this date.

The features of this style which principally distinguish it from all others are, the lancet windows, the thin isolated and clustered shafts, the buttresses and pinnacles, the foliage, the mouldings, and the sculptured ornaments and figures ; all of which must be studied with care in order to understand and appreciate fully its peculiarities, and will be found generally to determine the dates of the churches. The windows are of various kinds in the early period : the lancet windows, long and narrow, of one light, were most frequently used, with merely a small splay on the outside, and without any label moulding ; afterwards they were surmounted by labels, which, being continued horizontally from window to window, formed a string-course between them. Two lancet windows under a single drip-stone are sometimes met with, but in the most beautiful specimens of this arrangement the jambs and

* Bloxam's Gothic.

† This, as well as the Perpendicular, or Late Pointed, is peculiar to our country, as nothing similar is to be found in any buildings abroad.

the pier between the openings are ornamented with slender shafts, crowned by moulded capitals, and surmounted by the mouldings of the arches, over which are moulded double labels. The next arrangement is that of a triplet, or a combination of three windows together, that in the centre being higher, and in some cases larger than those at the side : the arrangement of columns in front of the piers and on the jambs, as well as the arch and label mouldings, is similar to the last noticed. These windows, in the smaller parochial churches, are most frequently placed at the east end of the chancels, and are only splayed, or very slightly decorated with mouldings. The combination that next demands our attention, in consequence of its evincing the germs of another class of Gothic architecture, and by its being the first approximation towards the introduction of tracery in the heads of windows, is that in which a part is pierced over a double lancet window, comprised within a single drip-stone. Circular windows were frequently introduced during the prevalence of this style, and were inserted above other windows within the angular part of gables.

The doorways of this style vary considerably both in form and in the arrangements of the arch mouldings and the supporting columns : in some cases the columns are single detached shafts, placed in a receding angle, whilst in others we find them in three or four receding spaces, and sometimes connected by bands or otherwise moulded : the upper mouldings of the capitals were mostly continuous, and from them sprung assemblages of small bead and hollow mouldings, in which the tooth ornament was frequently introduced. In the cathedrals and large conventual churches we meet with double doorways, divided by clustered columns or ornamented piers, and enclosed by a two-centred arch ; the space above the openings being filled either with sculptured figures and ornaments, or else by moulded quatrefoiled tracery. In some of these the heads of the openings are cinquefoiled, and richly decorated with mouldings and sculpture.

The pillars usually consist of small shafts (often of Purbeck marble), arranged round a circular pier, and connected by a band of mouldings at half the height of the shafts, and at the capitals and bases : others of different kinds are to be found ; a circular or octagonal pillar is common in country churches, which is crowned by moulded capitals, in which the nail-head and tooth ornaments, and also the rich flowing foliage of that style, are used. The buttresses of this date were often very prominent, and are frequently carried, with occasional weatherings, to the tops of the parapets, and terminated either by high pyramidical cappings, or else by acutely pointed pediments. Buttresses at this period were seldom placed diaganally at the angles of the buildings, although such disposition in the succeeding style was very general. The angles of the buttresses were frequently chamfered, or else small shafts, not projecting beyond the face, were introduced. The carved foliage is very remarkable for boldness of effect, and was much used in capitals, brackets, bosses, crockets, and spandrils; it was often so much undercut as to be connected with the mouldings and backings only by the stalks and edges of the leaves. There is generally a stiffness and mannerism in the combinations of the sculpture of this era, but the effect of it is almost always so beautiful, that we overlook its unreality in the great flexibility and freedom both of the conception and execution. The prevailing leaf is a trefoil; this was also used to form the crockets, which had their origin in this style.

"The Decorated, or Geometric Middle pointed style," dates from A. D. 1274 to 1377, during the reign of the three Edwards.

The Decorated style is of two characters, which can be easily defined by the nature of the traceries of the windows, and should be denominated "early and late decorated." In the former, the geometrical figures prevail, consisting of combinations of circles, trefoils, quatrefoils, cinquefoils, and triangles. It is remarkable for the harmony of its forms.

The tracery and cuspings were fully developed; and the uniting of several openings as a whole under one arch, or a succession of concentric mouldings, marked an evident deviation from the arrangement and principles of the Early English architecture. This Geometric Middle Pointed style may be considered to have been in use until about A. D. 1327, or the beginning of the reign of Edward the Third, when the compositions of the windows seem to have undergone a change, and the flowing or wavy lines succeeded, producing an almost endless variety of combinations. At the period to which we now refer, viz., from 1327 to 1377, the architecture of this country may justly be considered to have attained its greatest excellence, both as regards graceful proportion and a luxuriant profusion of beautiful ornament and mouldings. By very gradual progression, and almost imperceptible changes, had these principles of graceful design and unequalled beauty of execution been arrived at; and it cannot be denied but that the architectural art of this period was neither equalled nor surpassed in any other country or in any age.

The general plan of ecclesiastical and monastic buildings of this era was little marked by any deviation from that which preceded it: any change in the arrangement is to be attributed more to the requirements of the situation than to any alteration in the principles. To the details and parts of the combinations we must look for the distinguishing peculiarities. Throughout the century during which this style prevailed, the same kind of arch was generally used, and was either equilateral, obtuse-angled triangles, or segmental in form. The mouldings consisted chiefly of quarter or three-quarter rounds, with fillets, and in small churches double recessed splays alone were used: the deep hollows and unfilleted beads of the former style were quite discontinued.

The piers of this period, on which the nave arches rested, were frequently composed of half or three-quarter cylindrical shafts, which in some instances had small fillets at their

greatest projection, and in others smaller shafts or filleted mouldings were placed at the junction of the large shafts: this arrangement differs from the Early English in the columns being more closely united. The octagonal, cylindrical and circular pier is more generally to be found in small churches. The capitals are more frequently bell-shaped, crowned by quarter-rounds, fillets, and other mouldings, and having at the lower part a beaded or chamfered astragal. In the richer instances, or in large churches, the capitals were either numerously moulded, or ornamented with light elegant foliage, distributed completely over all parts of the capital but the abacus and the astragal; figures, battlements, and the ball-flower were frequently introduced on it. The bases of the piers differ from those of the preceding style, in their being composed of two or more small round mouldings, with either a quarter-round or hollow below, and beneath it a splay or curved moulding was sometimes introduced. The ogee form was in some cases used, but it more frequently denoted a later period. In plan, the base mouldings take various forms, not always following that of the shaft, but changing from the circular to the octagonal, and from the octagonal to the square.

The windows of this style, as we have before stated, differ from those of the Early English style, in having their openings connected and blended together either by geometrical or flowering tracery comprised under two-centered arch mouldings. They are generally large and of good proportion: those which were placed either at the east or west fonts, or at the transepts, varied from three to seven lights each, and were divided by mullions, which at the springing of the arch branched out either into geometrical or flowing combinations. The great variety of the traceries in windows of this style renders their description extremely difficult. In the best and most perfect instances, we find a principal and subordinate arrangement; the extreme mouldings bounding the general forms, whilst the secondary or inside mould-

ings mark the disposition and form of the lights. It is scarcely necessary to observe, that these harmonious arrangements of flowing lines were not produced solely from a correct perception of beautiful forms, but were grounded on that consummate skill and mathematical knowledge for which the freemasons of this country were so eminent. Square-headed windows were very frequently employed, both in the aisles of the smaller churches and in the clerestories; in many of them the ball-flower is inserted into the hollows of the jambs and along the top mouldings, and sometimes it is introduced into the under mouldings of the label. Segmental, flat-headed and circular windows were likewise used. Windows of triangular form, having the sides curved and filled in with tracery, are likewise peculiar to this date, and either used to fill up the angle of the gable or in clerestories. Square and diamond-shaped windows are sometimes introduced in churches of this period.

The buttresses of this style are more varied in form and disposition than those which preceded: in the smaller buildings they are generally of two stages, and frequently finished by gable-headed terminations, sometimes adorned with crockets and finials. A gable is sometimes introduced at the middle weathering, and at the top there is only a succession of weatherings or moulded water tables, with a splay and half round moulding at the nosing or greater projection. Traceries and panels are frequently sunk within the faces of the buttresses of the large ecclesiastical buildings. Niches were likewise made in some of those attached to parochial churches. Except in large buildings, where the buttresses have pyramidical terminations, the gable heads are not carried above the parapets. In many cases both the heads and set-offs are weathered and splayed without enrichment: the buttresses of this date were placed at the angles, or diagonally with the faces of the walls. Flying buttresses were also used.

The niches of this period were generally surmounted by

canopies of a pedimental or ogee form. The parapets were pierced with trefoil and quatrefoil openings. Gurgoyls, or grotesque figures projecting from the walls, were first employed to conduct the waters from the gutters Concerning the other minor details, we cannot now speak.

We have now reached the "*third period of the pointed style*," which may be dated from the latter part of the fourteenth century to the commencement of the sixteenth, or early in the times of Henry the Eighth. The general peculiarities of the fully developed style of the fifteenth century are chiefly visible in the increased expansion of the upright and square tendency of the tracery of the windows, the gorgeous, fan-like tracery of the groinings, the four-centered arches and horizontal lines of the doorways, the excessive decoration of the wooden roofs, and in the decoration of heraldric enrichments and color.

The next class is "*The Castellated and Domestic Buildings of England, from the Norman to the Tudor Times.*" The buildings of the Anglo-Saxon nobility, as well as those of the burgesses and common people of England, were of a very humble character, and consisted of timber covered with reeds and straw: the former, says William of Malmsbury, "squandered their ample means in low, mean dwellings." On the settlement of the Normans after the Conquest, the kings, nobility and prelates erected large and magnificent palaces or castles; and the barons were equally jealous in raising fortified castles, as were the priests in erecting fortified buildings. This change, like all others in the art of building, was the result of necessity: the Normans found, that although they had conquered, and intended to retain possession of the country, yet they were surrounded by vassals by whom they were detested, on account of the plunder and subjugation to which they were compelled to submit. During the reign of Stephen, from 1135 to 1154, no less than 1115 castles were raised from their foundations. An eminence near a river was the situation usually chosen: the boundary walls were often of great extent, and in plan very

irregular, their form being regulated by the nature of the position, or levels of the ground: the whole was surrounded by a broad ditch, called the fosse, which could be filled with water when required. The most advanced work beyond the fosse was the barbican or watch-tower; it was placed before the drawbridge and principal entrance, as a protection from sudden assaults: these outworks were of great strength, and so planned, that if the gate was forced, those within could still annoy the assailants from the turrets and embrasures during their attack on the drawbridge entrance. Within the ditch was a wall of great strength, frequently from 8 to 9 feet in thickness, and as much as 30 feet in height; towers were placed at the most commanding or principal positions of it, in which the principal officers of the castle resided: inside of the wall were the apartments for the retainers, servants, as well as storehouses and necessary offices. On the top of the wall was a platform extending the whole length and over the towers: the side towards the ditch was protected by battlements. The great gate was flanked on each side with a square or circular tower, and above the gateway were rooms which communicated with those in the towers. The mode of protecting this entrance was by a portcullis, or framework of wood faced with iron; it was fixed in a groove, and was raised or lowered by machinery; behind this were massive oak double doors, which were either covered with iron or large nail-heads. Within the external wall was a large open space or court, containing the chapel: in some instances another ditch or wall enclosed an inner court or ballium, where the dungeon or keep was placed. This great tower, the principal stronghold of the castle, was built on the most elevated spot, sometimes on an artificial mound, and varied from four to five stories in height. The walls were of great thickness, and in them the passages or stairs were built: the openings were small, and admitted but little light into the apartments. This building was used as the residence of the owner, or constable of the castle, and was

provided with underground vaults for the confinement of prisoners. On the second floor was the state room or hall for entertainment, as well as a chapel. This mass of masonry was made to contain provisions and ammunition for a long defence, in the event of the rest of the castle being taken: the well was usually in the centre of the tower, and had openings to each floor.* The only admission to this tower was by a door at from 15 to 20 feet from the ground, approached by a steep external staircase. The whole of this strong building was surmounted by projecting battlements and machicolations, through the openings of which arrows, stones and other missiles were thrown on the assailants. In the beginning of the fourteenth century, the habitable began to change into the castellated mansion.

The Domestic and Civil Architecture of England of the Tudor and Elizabethan periods, differ from the preceding in its applicability to domestic as well as ecclesiastical structures.

In the ornamental domestic architecture of the fifteenth and sixteenth centuries, generally designated Tudor, (there are very few examples before that period,) we perceive the same style as that of the ecclesiastical buildings applied to another class, where, although the parts are somewhat differently composed, the style of ornament and detail is essentially the same. Some features, such as doorways and porches, are very little altered from those of churches; while others, unknown to the latter class of buildings, such as chimneys and projecting windows, became highly characteristic and decorative in this. Oriel and bay windows are peculiar to this style: these terms are often used indiscriminately;—the former of these project out in the upper part of the building, and overhang that below, being corbelled upon mouldings splaying downwards on every side: the latter may be similar in openings and ornament, but they rise immediately from the ground, and are connected with the building by the base and string-course mouldings. Oriels are both

* Those at Rochester and Conisburg are still existing.

single and compound, that is, are either confined to one of the upper floors of the building, or carried up through all its stories.

Although chimneys had been long invented, and were much in use for other rooms, our ancestors do not appear to have introduced them generally into their halls until the end of the fifteenth or the early part of the sixteenth century. The previously open hearth, on which the fire was made, was in the centre of the hall, and the smoke escaped through the louvre lantern in the roof: about this period they were added to many halls of an older date.

The general plan, as we have before observed, of the larger mansions of the Tudor period was quadrangular, consisting of an inner and base court, between which stood the gate-house: on the side of the inner court facing the entrance, the principal apartments were placed; these consisted of the hall, the chapel, the great chamber and dining-room, and were connected with a gallery for amusements, running the whole length of another side of the quadrangle.

The great halls in the palaces, mansions and colleges of this period were extremely lofty, frequently predominating over the surrounding buildings: the ceilings and roofs were very boldly constructed and elaborately ornamented.

The reign of Elizabeth is remarkable for the introduction of a style of domestic architecture more systematic in plan, more commodious in its arrangements, and imposing in its effects, than any preceding. Up to this period the mansions of the nobles were only one story in height, and in plan greatly deficient in the requirements incidental to the improved social condition. Indeed, the domestic architecture under Elizabeth had assumed a more scientific character, and we have ample evidence that no building was now undertaken without the previous arrangement of a well considered plan. Books on the arts of design and construction were now published, and architects had begun to act upon a system in the construction of the palatial houses of the aristocracy. The

principal deviation from the plans of the Tudor houses was in the frequent introduction of bay windows; the improvement in the galleries, which were now generally lofty, wide, and more than 100 feet in length; that of staircases, from being small and inconvenient, to occupying a considerable portion of the mansion, and communicating with the entrance or staircase halls of spacious dimensions. The exteriors of the porticoes were greatly enriched with carved entablatures, columns, pilasters, figures, armorial bearings, and every variety of device which the most fantastic imagination could supply.

To houses of this date, terraces of great grandeur were generally attached, connected with each other by broad flights of steps;—they were bounded by richly perforated parapets or balustrades. The windows retain more of the Gothic character than any other feature; they were divided by mullions and transoms, although their height, as well as width, was generally much increased: in some examples there are three or four tiers of openings, diminishing in height as they ascend.

The Italian Orders are much introduced, but their classic proportions not attended to: the columns, pilasters, and piers are usually banded in several courses by square blocks, which are constantly decorated with diamond or jewel-shaped projections: this ornament is of very frequent occurrence, and may be considered as a distinct characteristic of this style. The entablatures are more usually broken, either by projecting profiles or scrolled and voluted ornaments. The bay windows, parapets, and gables are terminated in general by perforated ornaments of either a square, circular, or scroll form.

This singular manner of designing must be examined to be well understood; no description can possibly convey a just idea of its complex forms and elaborate ornaments. There is perhaps no class of English architecture more compounded of inconsistencies, defects, and beauties, than this

mixture of Gothic and Italian; but to be properly appreciated, it should be studied with a mind unbiased alike by the tendencies of a previous education and the indiscriminating caprices of fashion. The application of this style to country mansions is unquestionably not to be equalled by any other, as its varied forms of plan and outline will either harmonize or contrast beautifully with scenery of any description.

One of the most celebrated architects of the reigns of Elizabeth and her successor was John Thorpe, who designed and erected most of the principal palatial edifices of the time. The general form of his plans is that of three sides of a quadrangle, and the portico in the centre. When the quadrangles were used, they are surrounded by an open arcade or corridor. Bernard Adams and Lawrence Bradshaw, Robert and Huntingdon Smithson, were also eminent architects of this period.

The plaster ceilings of the Elizabethan date are particularly deserving of attention, on account of their richness and beautiful arrangement: the fire-places, paneling, cornices, friezes, and ornaments of the principal apartments, were extremely varied, and generally good in design.

The early part of the seventeenth century, during the reign of James the First, is the period of the introduction of unmixed Italian architecture into England: it is to be attributed to the genius of Inigo Jones, who, in the early part of his professional career, had erected and altered several large buildings in the mixed style, which continued to prevail until his masterly designs of the Venetian school caused a general admiration and adoption of this class of art. Little is known of Inigo Jones or his works as an architect previous to 1605, when James the First visited the university of Oxford, at which time he was employed on the quadrangle at St. John's college, and had been to Italy: from that time until his second visit, the buildings on which he was engaged were of a mixed or transition character; when, by a careful

study of the works of Palladio, he perfected his taste, ripened his judgment, and laid the foundation for his future well-merited reputation. On his return to England he was appointed to the office of Surveyor of Public Buildings, and from that time his fame and practice rapidly increased.

The numerous works executed by Jones have received, at different times, both praise and severe criticism : it must be admitted that his admiration of Palladian architecture sometimes led him to adopt plans and arrangements for houses not altogether suited to our climate or habits, and to aim at a splendor of design, which, under the circumstances, could not be accomplished. The combination of his windows was Italian, and the piers between them were frequently so large as to offer too much obstruction to the admission of sufficient light. Objections have been offered to the height of his roofs, and the unmeaning, as well as useless, introduction of porticoes in the centres of his façades. The encouragement received by Inigo Jones was brought to a close by the misfortunes of his royal patron: art or artists found so little favor or encouragement during the time of the Commonwealth, that, unmindful of his talents, he had to pay £545 as a penalty for being a Roman Catholic. Disappointment and trouble accelerated his death, which took place in 1651.

The fire of 1666, which destroyed nearly the whole of London, was the occasion to which Sir Christopher Wren was indebted for the opportunities of displaying his skill in architecture and constructive science. One of his first designs was that for the rebuilding the city on a regular plan, which unfortunately was never carried wholly into effect,—and is the more to be regretted, as we then should have been spared the inconvenience resulting from our present bad arrangement. The task of re-erecting the cathedral of St. Paul and the greater part of the churches in the city was intrusted to Wren, whose distinguished talents were fully equal to the stupendous undertaking. No architect, before

or since his time, has possessed such a variety of knowledge, both in design and coustructiou: the multiplicity and magnitude of his works proclaim the universality of his genius. The same hand produced the noblest of modern cathedrals, the largest palace, hospitals, and numberless public and private buildings, besides twenty-five churches in the city of London. Great length of days were bestowed on him;—"he lived to enrich the reigns of several princes, and disgraced the last of them;"—(at the advanced age of 86 he was removed by George I. from the office of Surveyor General;)—"he restored London, and recorded its fall;"—he designed and lived to complete a building which is the boast of England aud the admiration of the world, of which a general description is all that we can give.

The cathedral church of St. Paul stands on a greater portiou of the site of the old one: the designs were approved by Charles II., and the warrant issued for the execution of the works on the 1st of May, 1675. The first stone was laid on the 21st of June, 1675: within ten years the walls of the choir and aisles and the north and south porticoes were finished, and the piers of the dome were brought up to the same height. The highest stone on the top of the lantern, which was the last, was laid by the son of the architect, in 1710. The whole edifice was completed in thirty-five years, having only one architect, one master-mason, and the see being occupied the whole time by one bishop.

The plan of St. Paul's is a Latin cross, measuring from east to west 480 feet; its general breadth on the exterior is 125 feet, and from the north to the south ends of the transepts 280 feet. The western end of the edifice is flanked by towers on the same plan as the walls, but projecting 27 feet beyond the north and south walls, thus making the whole width of the façade 180 feet. The exterior of the building consists of two Orders;—the lower, or Corinthian, stands on a basement 10 feet above the ground, which is the level of the church, which on the western side is approached by a

magnificent flight of marble steps, extending nearly the whole breadth of the front. From this level to the top of the entablature, or the whole height of the Order, is 50 feet; and from this to the upper part of the second Order, which is Composite, is 40 feet; thus making the whole height of the body of the church 100 feet from the ground. A magnificent portico, of the two Orders in height, ornaments the western front; the lower story consists of twelve coupled columns, and the upper of eight, besides four pilasters; this portico is surmounted by a pediment, on whose tympanum the subject of the conversion of St. Paul is sculptured in high relief. At the ends of the transepts are porticoes, in form of a segment of a circle, round which are six fluted Corinthian columns; this is crowned by a half-dome, resting against the wall of the building.

In the absence of an elevation and section of the dome and lantern, it would be nearly impossible to give a satisfactory description of the constructive peculiarities of this and other portions of the building; we must therefore content ourselves with only giving the dimensions. The height from the pavement to the opening of the inner dome (which is of brick-work) is 168 feet, and its diameter 100 feet. On the haunches of this dome, at 200 feet from the pavement, rests the base of a cone of brick-work, the top of which is 285 feet from the level of the church: this carries a stone lantern 55 feet high, terminating in a dome, and above this is a ball and cross. The external dome is of oak, covered with lead, and is supported by horizontal and vertical timbers resting on corbels fixed in the brick cone. The lateral thrust of the cone and the interior dome is restrained by four tiers of strong iron chains, bedded with lead in grooves cut in the masonry at the base and at different heights on the exterior of the dome. The towers at the extremities of the western front are 220 feet high, and ornamented with Corinthian pilasters, terminating above the roof of the church in open lanterns, and covered with domes. On the exterior of the building,

the intervals of the columns and pilasters are occupied by niches or windows with semi-circular or horizontal heads, and crowned by pediments. In the upper Order of the north and south sides there are no windows, as it is merely a screening wall to the nave.

This edifice may, for elegance of design, bear comparison with any in Europe, not even excepting St. Peter's at Rome, though it is far from being so large. It must be admitted, however, that the interior faces of the walls present a naked appearance, and require much embellishment from ornamental sculpture before they will harmonize with the richness of the exterior. A great defect also arises, in the interior, from the want of connection, which is caused by the arcades interrupting the entablatures. Sir Christopher Wren appears to have surpassed all those who preceded him in the skill required for raising a building on the minimum of foundation. Some criterion may be drawn of the comparative skill employed in the construction of other buildings somewhat similar, by comparing the ratio between the area of the whole plan and that of the sum of the areas of the whole of the piers, walls, and pillars which serve to support the superincumbent mass. To produce the greatest effect by the smallest means is one of the first qualifications of an architect, and the similarity of four churches affords a criterion of their respective merits as to the least amount of solid for area.

Wren lived to complete St. Paul's (which cost £736,752, exclusive of the stone and iron enclosures round it, which cost £11,202): he died in 1723, at the age of 91, and was buried under the fabric,—with four words—

SI QUÆRAS MONUMENTUM CIRCUMSPICE.

At the commencement of the eighteenth century flourished Sir John Vanbrugh, who built edifices after fashions of his own.

After him came James Gibbs, who built many churches and other buildings; then came Sir William Chambers, the

architect of Somerset House and the author of an excellent work on civil architecture.

England to-day practises all sorts, and has no distinctive style of its own.

BOOK III.

CHAPTER I.

Definition of Architecture—Its Necessity, Uses and Requirements.

"Well building hath three conditions : Commodity, Firmness and Delight."
SIR HENRY WOTTON.

ARCHITECTURE is the art of well building; in other words, the perfect adaptation of a building to each of its parts, and to the purposes of its building. There is a wide difference between the art of Building, and Architecture—but none between Architecture and *well*-Building. No building is well built which does not, in addition to all its utilitarian purposes, evince the greatest beauty capable under the circumstances, to attract the attention, to exercise the fancy, to subdue the passions, to call forth the aspirations, or to dazzle with its imposing majesty, as may be most appropriate.

The contemplation of perfection is always the contemplation of a thing of Beauty. Perfection is always beautiful, and truly has it been said of Architecture, or well-building, that it is "the art of the beautiful in building."

The contemplation of "a thing of beauty is a joy forever," and rightly has Sir Henry Wotton said that "Delight" is an inseparable condition of Architecture. That building which awakens not in the human breast feelings of pleasure or delight, is not well-building, or Architecture.

In no civilized country is the art of true Architecture less understood or practiced than in the United States. True, we have buildings which are perfect samples of nearly every style, character, and order of architecture, which has ever been known in any portion of the globe. But there is a prevailing sentiment too common among our people, that if

it be " firm or stable," and commodious or convenient, that all that is required is had. This sentiment was never learned by man from nature, nor does he act upon it in his other occupations and pursuits. The rain that descends from the heavens to moisten the earth and to nourish vegetation, fails not while doing its *work* to paint the beauteous rainbow to please and gladden the hearts of all observers. Our countrymen should have it impressed upon them that even though their buildings be convenient and stable, unless they show all the beauteous perfection which the circumstances admit, they are neither architectural or well-built. Buildings may be sometimes perfectly fitted to their purpose, and yet not only devoid of beauty, but positively hideous and disgusting to the eye. There are four points quite necessary to be kept in view in Architecture—Politeness, Beauty, Expression and Poetry.

1st. *Politeness.* From the time that selfish Cain, the first-born, beat down as an enemy and destroyed his brother Abel, the second-born, to the present day, selfishness has been a dominant and degrading principle of manhood. As manhood grew in the human breast, so selfishness began to die. Step by step may we see man's exclusiveness expanding from self to the family, from the family to the tribe, from the tribe to the nation, till to-day we see manhood owning man for his brother. He even does not now consider that edifice or structure well-built which does not, in addition to its purposes of utility, possess that beauty which will awaken manly pleasure and delight in the breast of every brother man who contemplates it. That selfishness which erects buildings with a single eye to the convenience of him who builds them, has died out. The fraternity of manhood requires that it must be adorned with beauty, built with propriety, fitness and order, so as not to offend to the *sense or taste* of men, but to please, to amaze, or to compliment them.

2d. *Beauty* is ever associated with perfection, not ornament.

The beauty of simplicity far exceeds the mock beauty of gaudy, showy ornamentation. The beauty of simplicity never fails to call forth admiration. Beauty is not capable of division into its constituent parts—its very essence consists in its wholeness. Our limits will not permit us to follow our author in his attempt to divide under general heads the various parts of beauty.

3d. *Expression.* Education is not required to feel the expressiveness of art; give us the mind wholly uneducated in it; give us the rustic or the child unused to cities, uncorrupted by the sight of abused architecture, and he shall immediately feel in the true art all its intended effects,—shall be awed by the sublime majesty of the Doric, or raised by the heavenward aspiration of the Gothic temple ; soothed by the mild repose of Palladio, and enlivened by the playful fancy of Scammozzi; sobered by the severe purity of the Greeks, and relaxed by the picturesque riot of Vanbrugh ; attracted by the inviting urbanity of the Vicentine villa, and repelled by the gloomy frown of the Florentine castle. Among pieces of true architecture he shall not need to ask which is the temple, and which is the forum. He shall know at a glance the festive theatre and the stern hall of hoodwinked justice, the modest hospital and the patrician palace. He shall not mistake what is public for what is private, nor fail to distinguish which buildings are dedicated to business, which to pleasure or to repose. All this is expressed by art, not conventionalism, and is intelligible to the perfectly *artless*, as well or better than to him of cultivated taste—and why? Because the cultivation required does not consist in *learning*, but in *unlearning* the prejudices of a life, —in getting rid of the mass of falsehood imbibed during years passed in the presence of an indiscriminate mixture and misapplication of every thing that is expressive in architecture; the abuse of employing it all alike, for the sake of *ornament* instead of *propriety*, fancy instead of discretion. In the culture required to feel rightly the effects of this art,

there is nothing to be learnt, but every thing to be unlearnt. The savage and the highly cultivated are alike in this respect; or rather, the acme of this cultivation is to approach as near as possible to the feelings of the totally ignorant,—of one to whom all architecture is new. But to those brought up in modern English cities this is perhaps impossible, (I do not mean in its perfection, but in such degree as to be useful,) so completely must their natural sense of right and wrong become in this respect deadened and subverted, by the time their education is complete.

If there be no differences of expression in architecture, then is it no fine art, but a trifle beneath the notice of an educated man, and which must soon find its level, by sinking into the hands of mere constructors and decorators.

Definite expression, though almost forgotten and become a dead letter, in modern English architecture—though almost above the reach of the art in its present state—is yet not the highest aim of that art, in its complete form. It is acknowledged that this, in common with all the arts of expression, presents in its most excellent works a merit or merits not to be described or conveyed in any other medium than the art itself,—moreover, a degree of excellence superior to mere expression, because capable not only, like that, of reaching and affecting the mind, but also of elevating, refining, or improving it.

In the want of a better term, this portion of each art has been called its poetry,—a very questionable application of the name of one art to express a particular portion of another. However, we must take words as we find them, and content ourselves with distinguishing the *things* to which they have been applied.

Poetry, in its ordinary and strict acceptation, cannot exist where there is no language—no assertion made—no story told—no idea stated. Now, we have denied to architecture the power of doing this. The phonetic arts, viz., historical painting and historical sculpture, may do it : they speak a

language—a natural and universal language—and therefore may be poetical, in the strictest sense of the word. But architecture, like music, has no natural language, and is only degraded when it attempts to speak an artificial one by means of conventional signs. Nothing can be pushed out of its proper sphere without being degraded; in a lower sphere it is cramped, and its highest qualities stifled; in a higher, it is equally degraded, because its inability to do what is required of it, is exposed. Architecture is not exalted by attempts to render it phonetic,—to make it serve the purpose of a language.

Where there is no language, there can be no poetry, in its strict sense; yet we hear of the poetry of music and of architecture; hence this term must here be taken in a more extended sense. It may be understood in three ways: *first*, as applying to the untaught portion, or that portion which transcends the rules and theory of the art in their present state; *secondly*, as including those beauties or perfections in each art, which are not, or have not been, conveyed in any other,—consequently, not in words; or *thirdly*, as applying to those qualities by which its highest productions are calculated to produce, not only a transient emotion, but a permanent effect on the beholder. In either case, the precise limit of the application of the word must be vague: the lowest production in which any poetry may be considered to exist, cannot be exactly pointed out; but of its existence in the highest efforts of the art, there is no difference of opinion.

Whoever wanders among the hundred columns of the great hall of the temple of Karnac; whoever, by the assistance of designs or models, and of the fragments in the British Museum, restores and rebuilds in his mind's eye, the small but glorious temple of the Athenian goddess; whoever climbs the ruined stairs of the Colosseum, to the edge of its artificial crater; whoever enters the cathedral of Amiens, or walks round the exterior of that of Salisbury; whoever views any one of these works of architecture, and finds no

poetry in it, must be incapable of discovering it in any thing else—in nature or in art.

There is, then, or rather there *has been*, such a thing as a poetry of architecture; and we may therefore, including this, consider the whole aim of "architecture proper," apart from building, under four heads,—politeness, beauty, expression, and poetry. It has been the object of the present chapter to point out to the reader this fourfold use of architecture: *first*, as a courtesy due, from every one who builds, to humanity, on whose ground and in whose sight he builds; *secondly*, as a further refinement of this courtesy into positive beauty, by attention to whatever may please the mind; and preference of what may please its higher faculties, before that which may please the lower, when they are incompatible; (the justice of this preference constituting the difference between right and wrong in art, commonly called good and bad taste;) *thirdly*, as a mode of conveying to the mind definite emotions, suited to, and even indicative of, the character and general destination of the work; *lastly*, as a means not only of affecting, but of exalting or improving. The architecture which attains only the first of these objects is no more than a *polite* art; when it reaches the second, it becomes an *ornamental* art; by attaining the third, (and not otherwise,) it gains a title to be considered a *fine*, that is, an *expressive* art: in those very few of its productions in which the last purpose has been accomplished, does it deserve to be called a *high*, a *poetic* art. As the first, its aim is to *conciliate;* as the second, to *please;* as the third, to *touch;* and as the last, to TEACH.

CHAPTER II.

Occular and Formal Beauty—First Generalization thereon—Unity and Variety—Graduation and Contrast.

It is the natural progress of instruction to teach first what is obvious and perceptible to the senses, and from hence proceed gradually to notions large, liberal, and complete, such as comprise the more refined and higher excellences in art.
SIR JOSHUA REYNOLDS.

GREAT difference exists among writers with respect to *occular* and *mental* pleasure—some contending that such a distinction in fact exists, while others deny it, and assert that the eye experiences no more pleasure in contemplating one thing than another—that is, considered apart from mental inferences and associations.

It would seem, however, that the eye has its choice of *color*, for children and savages, in the choice of colors, consulting nothing beyond the immediate gratification of the eye, invariably prefer a certain class of colors—those termed crude or positive—to another class, those which we term dull colors or tones. This is a mere sensuous preference, like that of sound or flavor.

The discovery of a physical reason for the preferences of the eye must be considered one of the greatest triumphs of inductive science. It is perfectly known that the difference is the *same* in the senses of sight and hearing. The most pleasurable sensations are produced by the inconceivably rapid repetition of vibrations or pulsations very regularly or even timed. The dead or duller colors are caused by the *irregular* vibrations.

The *harmony* of colors, that is, the preference given to a juxtaposition of colors, rather than to that of any other two, though equally bright or pleasing when seen separately, must be wholly an occular beauty; for the *mind* cannot (by the direct evidence of unaided sense) discover any relation

between red and green, for instance, which does not exist between blue and green. We can only say that the former harmonize, and the latter do not. As the mind knows nothing, in general, about this harmony, the mind can have nothing to do with the appreciation of it. The cause of this harmony is: two sets of vibrations which are each regular in itself, and which bear a simple ratio to each other, by uniting together, form a vibration which is therefore regular and musical; but two vibrations which, however regular each may be alone, bear no commensurable ratio to each other, will, by their union, produce a totally irregular vibration: that is, *a noise.* There are many nice discoveries—perhaps nothing more than theories—concerning the cause of harmony of colors. On the whole, it would appear that the laws of coloring, as a gratification of the eye only, are simply these:

1. That the more regular the vibrations of any given color may be, the more pleasing will it be in itself, apart from fitness or association with others.

2. That, as these isochronous colors—(colors caused by regular vibration)—have a more exciting effect on the retina than those which are of the same brightness but not isochronous, the repose afforded by a change from the former to the latter is also grateful; so that we should follow the example of nature's works, throughout which the sober, mixed or subdued *tones* are the rule, and the pure or isochronous *colors* the exception; for it is a less evil to be able to find excitement, than to be able to find repose.

3. That *variety* of coloring is abstractly (without reference to fitness, &c.,) more pleasing than monotony, especially when the colors that adjoin each other have their vibrations in a harmonic ratio; that is, when they form contrasts, and still more when they are varied in intensity or brilliancy, or both, as well as contrasted in quality.

4. That, as variety is an exciting quality, owing to the rapid changes which each point of the retina undergoes,

the change from variety to sameness of color is required for repose; so that here, again, we should imitate nature, in which *sameness* of coloring is the rule, and *variety* the exception; the former being found in all large and grand objects, and the latter only in small and scattered organisms.

Many writers have attempted to apply "the harmonious" theory of proportion to the dimensions of buildings, without any satisfactory result.

Equal-timed or equal-spaced repetition is confessedly beauteous. It is adopted in all the higher arts, and leads to the rhythm of poetry, or the equal spacing of the windows of a palace.

I believe the chief charm of this quality of architecture is to be traced to its expression of courtesy and consideration for the spectator. There is another kind of beauty in visible objects, which is commonly, but perhaps falsely, supposed to speak to the eye; this is that kind of symmetry or uniformity which consists in an exact correspondence of form between the two halves of an object. To distinguish it from other kinds of uniformity we will call it the *uniformity of halves.* We need hardly observe that it is the most universal in its nature, pervading all ranks of organic life, from the leaf and the flower up to man; and all separate and distinct creatures, even when inorganic, from a crystal to a world. It is to the minor ornaments of architecture that we must look for its illustration, and not to general forms, principal members, or any constructive features, because fitness of destination, definite expression, and other higher excellences, will always, in them, interfere with and should prevail over mere formal beauty.

In analyzing such examples of ornamental forms we shall find the chief properties common to them in all styles, to be those which are here mentioned, viz :—

1. *Equal-spaced repetition,* exemplified in all description of diaper patterns.

2. *Uniformity of halves;* which sometimes has place not

only in one direction, or on each side of one axis or plane of division, but is related to *two* such planes at right angles to each other, or to *three* intersecting each other in a single axle, and dividing the object into six equal sectors, or to *four*, *five*, or any number of such planes, subject to the same condition; all which practices are evidently founded on nature, in which a *single* plane of uniform division is characteristic of all the higher classes of animals, and of numerous classes of flowers and fruits (the leguminosæ, papilionaceæ, &c.,): two such planes, or a *double* uniformity, though a rather uncommon arrangement, is not without example in many vegetable objects; a division by *three* planes, or into six sectors, pervades the flowers of monocotyledonous plants; a *fourfold* uniformity, or eightfold division, runs through those of the cruciferæ, &c.; and a *fivefold* belongs to the great majority of dicotyledonous flowers, and to the lowest or radiate class of animals.

3. *Preference of curves to straight lines.*—Every eye prefers the patterns composed of curves to those composed of straight lines, abstractedly, without reference to their situation, &c. ; and though every complete style of architecture presents ornament or tracery of both descriptions, it is easily seen that the rectilinear is introduced always from other considerations, abstract beauty, considerations of fitness, construction, consistency of character, &c.,—or else to give value to the more pleasing forms.

To these principles we may add,

4. *Preference of curves of contrary flexure* to those which have no such contrariety; the flowing tracery of the fourteenth century, for instance, to the (so called) geometrical tracery of the thirteenth, which is equally composed of curves, but without points of contrary flexure. Every one has heard of Hogarth's 'line of beauty,'—the letter S.

5. *Preference of curves of varying curvature* to circular ones. The main difference between Greek mouldings and Roman ones, between Greek vases and Chinese, is that the

former are composed with outlines of continually varying curvature, and the latter with circular arcs.

6. *Unity or consistency of character.*—Mixtilinear form or ornament is, in general, less beautiful than either that which is composed entirely of straight lines or entirely of curves. This will be especially the case when several straight lines fall together in one place, and several curves in another, because then the mixture of incongruous principles is most obvious. The defect is best counteracted when the straight and curved lines are equally distributed throughout, and especially when a general principle is seen to govern their use, that is, when all the straight parts have something in common *besides straightness*, and all the curved parts some common quality *besides* their curvature. The same remarks apply to the mixture of circular with variable curves, and, in general, to every attempt at mixing different *styles* of form. It can succeed only when some new law, that did not apply to either of the styles separately, is introduced and made to govern their respective use, and thus restore that consistency which has been violated by the mixture; and this law must be so extensively applied and strictly observed, as to be quite obvious to the spectator at a glance. Thus those ingenious decorators, the Arabs, wishing to combine the beauties and richness of two kinds of ornament, often did so without inconsistency by placing them on the same surface, but giving them different degrees of relief, or different colors, so that one appears superposed in front of the other, without interfering with it. The eye can follow each separately, as the ear follows the base or treble of a complex piece of music.

It is hardly possible to state collectively these proximate principles of beauty in form, without being led a step higher, to a generalization, which reduces them all to a broader principle, though still only a proximate one. This has commonly been stated as the *combination of* UNITY *with* VARIETY. It is best explained, perhaps, in the words of Dr. Hutcheson,

who states as an axiom, (with regard to mere formal beauty,) that where the uniformity is equal, the beauty of forms is in proportion to their variety; and when their variety is equal, their beauty is in proportion to their uniformity.

Unity or uniformity is here taken in its widest sense, as meaning oneness of *any thing*, of size, of form, of number, of ratio, of succession, of any quality, or any principle whatever; it is, in fact, synonymous with method, order, law, or consistency. It is so far opposed to variety, that they cannot exist together in regard to any one quality. Yet the beauty, of which we are now speaking, consists not as some most erroneously suppose, in keeping a "happy medium" between these two opposite principles. Such a rule, being merely negative, can lead to no positive beauty. This consists not in the avoidance of both the opposite qualities, but in just the reverse of this, in combining both in their greatest possible perfection,—in reconciling the extremes of both. Of course, this can only be done by the maintenance in all the parts of the composition, of perfect unity in regard to some one quality or circumstance, with the utmost variety in some other quality or circumstance. This is necessary to the display of any beauty, however slight; but its degree will be increased in proportion to the number of points of correspondence or unity, and of points of variety. Hence the designer examines and analyses the various qualities or circumstances of the parts of his design, in order to find as many points as possible in which they may be made to resemble each other, or to differ. Moreover, the number of points of resemblance, and of points of difference, must be about equal. If the former preponderate in number, we say the design is *monotonous*, or wanting in variety. If, on the other hand, the points of variety are greatly more numerous than those of unity, we call it *confused*, or wanting in character (*i. e.*, self-consistency.) These faults do not imply an absolute excess of unity in one case, or variety in the other, but only an excess relatively to the other quality—in fact, a

deficiency of that other quality. And it would be well if these faults were always so understood, and remedied not by *removing* a point of resemblance in the one case, or of difference in the other, but by *adding* the contrary,—by hunting out some new point of difference or resemblance, instead of abandoning an old one.

Neither unity nor variety can ever be carried too far, if, for every instance of the one, an instance of the other be also found. It is an error to say that, in any composition, one of these qualities is in excess: it can never be in absolute excess: it is the other quality which is in relative deficiency.

Let us now illustrate this principle by its application to the simplest cases of abstract beauty in nature and in art, leaving the reader to apply it to more complex examples.

It is extremely doubtful whether absolute unity, without any point of variety, can constitute beauty in any object. We have an instance of such a kind in a straight line of equal thickness and intensity throughout its length. There seem to be cases where this is admired, as in the sea-horizon, in a stratiform cloud, &c.; but we shall presently show that they would not be considered beautiful by themselves, and only become so by a relation with their accompaniments.

The case is very different when the line regularly diminishes in strength from one end to the other, as in the perspective image of a railway bar, a distant glimpse of a lake, or the sea-horizon in many cases. Here the unity of direction, in all parts of the line, is accompanied by a variation in strength, and, again, by an unity in the law of this variation.

Even without this latter kind of unity, a straight line, varying in thickness *irregularly*, as the angle of an old but firm building, is allowed to possess a beauty which it had not when new. How different is the edge of a warped brick, or an ill-founded building, which wants the unity of straightness.

An irregularly curved line is destitute of beauty because the variety (of direction) is obtained only at the expense of unity: not so with a circular arc; though the unity of *direction* is abandoned, there is a substitute for it in the unity of *curvature*. It is the simplest of lines that can be beautiful in itself without the aid of varying thickness; for, while its parts all vary in one respect—direction, they all agree in the rate of this variation, *i. e.*, in curvature. The beauty is doubled, however, by a regular variation in thickness; for there are now *two* points of variety, viz., in direction and in thickness, and also *two* points of unity, a constant rate of curvature, and a constant law of diminution.

But the circular curve is the least beautiful of all regular curves; for, in all others, an additional kind of variety is introduced, in the variation of curvature; and an additional kind of unity, in the constancy of the law of this variation. Without the latter circumstance, no increase of beauty, but the very reverse, would accrue from the mere variety; for it would be obtained at the expense of the unity of curvature. Thus the varied curvature in the haunches of the Tudor arch is generally considered a defect. When similar lawless variations occur more than once, they produce what is called a *crippled* curve, the ugliest of all lines.

The circle, then, is excelled in beauty by all other simple curves; but, fortunately, *perspective* remedies its defect, by rendering its ocular image almost always elliptical or hyperbolic.* It is a very rare case for the eye to be exactly in the axis where the circle can be *seen* as a circle, and in such a case we never hear its beauty admired.

All other curves besides the circle resemble each other as regards the exhibition of unity and variety; and, accordingly, we never hear of any preference given to one more

* Circles give a parabolic or hyperbolic perspective image when we view the interior of a domed building from a point perpendicularly under the circumference of one of its horizontal circles. The visible portion of *this* circle will then be projected as a parabola, and all *larger* horizontal circles as hyperbolas ; only those which are *smaller* than this, being seen in the usual manner as ellipses.

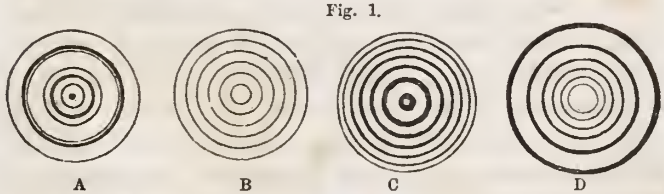
than another, on account of abstract beauty. Hay has shown that the most perfect forms of Greek pottery and ornament may be imitated by combinations of elliptic arcs. So they might, doubtless, by arcs of any curve of varying curvature. The *parabola* is admired in cascades and fountains; the *catenary*, in drapery and festoons; the *trochoid* and *epitrochoid*, in penmanship; the logarithmic *spiral*, in shells and volutes; and various kinds of *elastic* curves, in vegetation.

It may be doubted whether the repetition of similar objects at equal distances has any beauty except when seen perspectively. It is hardly ever possible (indeed impossible, if they be in a straight line) so to view them as to have their images formed on the retina, similar and equi-distant. Against unity of form and of direction, then, we have to set off variety of apparent size and apparent distance apart; this variety being still, in each case, subject to an uniform law of increase or decrease. There are thus more points of unity than of variety; and, accordingly, a series of this kind requires but little extension to render it monotonous.

If the series be arranged in a regular curve, this deficiency of variety is supplied without diminishing the points of unity, the unity of direction being replaced by that of curvature, &c., and thus the beauty is greatly augmented.

We may illustrate these principles by a figure (A) composed of concentric circles placed at random, and varying irregularly in every thing except their unity of form and concentricity. This can hardly be said to possess any positive beauty, though it would be beautiful by comparison with a figure in which they were either crippled or not con-

Fig. 1.

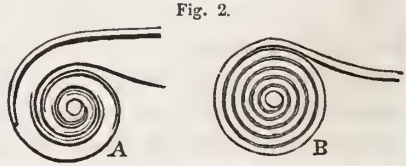


centric. We gain nothing by equalizing their thicknesses

and the spaces between them (as at B,) because this is simply substituting (in both alterations) unity for variety, which, in both cases, we abandon. But in C, the two principles are reconciled, the variety in the intervals being accompanied by the unity of a law regulating them all: thus a certain degree of beauty is produced, which is augmented by the introduction of another source of variety in the unequal thicknesses, and of unity in the regulation of these also, by an uniform law. The example D is added to show that it matters not how the variations occur, provided there be as many points of resemblance as of difference.

A series of quantities or dimensions, forming a progression of any sort, is thus always beautiful, however complex may be the law of the series. But the arithmetical progression is less beautiful than any other, for the same reason that the circular curve is less beautiful than any other. In *this*, the direction is indeed continually varying, but always at the same rate; and in *that*, the successive terms of the series increase or diminish always by the same increment or decrement. Both are improved, therefore, by exchanging this sameness (of the curvature in one case, and the increment in the other) for variety, provided this be regulated by one uniform law.

Fig. 2.



Hence the arithmetical spiral is the least beautiful curve of its kind, as any one will probably admit who compares these two examples, A being the ordinary form of the Greek Ionic volute, viz., a geometrical or logarithmic spiral, and B an imitation thereof, as it appears in the temple of a "mixed order," at the Greek colony of Selinus, in Sicily. This is the only instance I know of an *arithmetical volute,* a form well worthy of the bungler who could design such a piece of inconsistency as Ionic columns supporting a Doric entablature. Nature

affords instances of the geometrical spiral in every univalve shell,—of the arithmetical spiral in none.

A kind of iron fence has lately been introduced, in which the horizontal bars are placed at progressively increasing distances from the ground upwards. It shows how much beauty may be added to an object without adding anything else, except (in this case) stability and mechanical fitness.

Serial progressions, however, have little place in architecture, at least in the dimensions of principal parts, because equality always answers the same purpose, the equal divisions being reduced by perspective to a progressional series. We have an instance of an actual series of this kind, however, in the stories of St. Bride's steeple, which form four terms of a geometrical progression; and any one may easily convince himself that the smallest perceptible alteration in the height of any one of them would destroy the beauty of the whole;—a very different effect from any that is observed in deviations from the "harmonic proportions," on which some insist and place such reliance.

All the modes of combining unity with variety hitherto noticed, may be included under the term GRADATION. There is, however, another mode of effecting this object, on a totally different principle. Where there are only two objects or parts of one object considered, they may be made to correspond in certain respects, and vary greatly, or even as much as possible, in other respects; and this mode of reconciling unity with variety is termed CONTRAST. It is evidently opposed to *gradation*, since the two extremes are here brought together without any intermediate softening or preparation. Consequently there can be no compromise between the two modes of treatment. Whichever the designer adopts in any particular case, that principle and that alone must be carried out. In a curved line there is gradation (of direction),—in the meeting of two lines at an angle, there is contrast. So also in a curved surface there will be gradation of light and shade,—in the meeting of two planes,

contrast of the same qualities. In either case, the rounding off the angle would be an attempt to compromise between these opposite principles of beauty, and would lead to a sacrifice of both, without an equivalent; so that we need not wonder at this practice never having found favor in any style or in any age, however depraved in taste. To this, also, we may attribute the absence of the *hyperbola* from the extensive list of ornamental curves. It seems the only simple or well-known curve that is banished from decorative design, probably from its too near approach to the character of an angle rounded off, affording neither the beauty of contrast nor of gradation.

Contrast, then, consists in a perfect similitude between two adjacent objects in certain respects, accompanied by a wide difference in some other respect, or sometimes in two or three other respects, (in which cases we may term it double or treble contrast,) but the simple is more common. Resemblances are quite as necessary as differences, and indeed must be more numerous. There can be no such thing as contrast between two things that are altogether different. In most contrasts, they differ only in one point, and are alike in every other.

The uniformity of halves derives its beauty from a single contrast of the most perfect kind. In the case of a plane figure, the two parts are alike in every respect except position. They are repetitions of the same identical form, but so placed that we see the front of the one and the back of the other. In a solid body they are contrasted also in their mode of receiving the light, yet perfectly similar in form.

How much the beauty of such forms depends on the first mentioned contrast will appear by regarding those few cases of uniformity of halves, in which this contrast (of front and back) is omitted, as in the letters s and z, in which, however, the halves have still a contrast of position. But I know of no natural form composed on this principle.

In cases of uniformity related to several planes of division,

i.e. in starlike forms, the number of repetitions, or sectors, of similar form, is always *even,* and they are alternately reversed, front for back, in every natural example. Art, however, in times of depraved taste, introduced as a novelty, forms of this kind in which contrast is neglected, all the sectors presenting the same side to the spectator. This gives always the idea of rotation, whence the expression, a *turning* star or flower. This kind of form, of course, is proper for a wheel, but highly improper for any part of a fixed structure. Its non-occurrence in nature is sufficient to prove its inferiority also as regards abstract beauty.

Whenever Nature has repeated sectors of similar form, in this manner, without alternate opposition, she has supplied its place by introducing another element of variation, viz., in *size.* In this way, the whole class of univalve shells are composed, by a number of sectors round an axis, all alike in form, but whose sizes form a geometrical progression.

The beauty of curves of contrary flexure (Hogarth's principle) generally arises also from contrast. Hence it is a mistake to suppose that the passage from convexity to concavity should be *gradual;* that is to say, to say, that the curvature should continually diminish up to that point of flexure, become evanescent at that point, and then increase, as in the long italic *f*. This is what necessarily occurs in all curves, that have naturally a contrary flexure: but though these are appropriate to many purposes, and have a beauty of their own, this is quite distinct from that of the flexures which arise from the combination of *two* curves, and is much less frequently applicable. The former beauty is one of gradation; the latter, one of contrast: for as the change from one law of curvature to the other must take place at some definite point, it must be *sudden,* and partake of the nature of contrast.

In examining instances of this kind of flexure, it will be observed that the mere identity of *direction* in the two curves, at the point of contact, is not always sufficient to prevent

their appearing disjointed,—that is, deficient in unity. Hence some additional kind of unity should be sought to connect them, and this we may find in equality of *curvature;* besides which, the most perfect contrast requires similitude in all points except those which are contrasted: whence the contrast of two opposite and *positive** qualities (as convexity and concavity) will be most perfect when they are both equally removed from the mean (which in this case is straightness); whence we may infer that the deflexions of the two curves from their common tangent should be initially equal,—that is, their *curvatures* equal at the point of junction. Accordingly, in examining forms of this kind, it will be found that when faulty, their fault arises from the radii of the two curves, at their junction being too unequal; and in the Grecian forms composed of elliptic arcs, by Mr. Hay, it will be found that the most graceful bends are those in which the two ellipses touch at two points having the greatest equality of curvature.

As the change from one law of curvature to another must always have the nature of contrast, there appears no reason why we should seek to diminish this contrast without the possibility of gaining the opposite beauty—that of gradation, or continuity; for this can exist only where the law is continuous; or, in other words, where the whole is *one* curve. There appears, therefore, no foundation for the rule maintained by an eminent architect, that wherever two curves unite (not by an angle) it should be by a contact of the second order. To explain this, we must observe that lines may meet in an infinity of different ways. When they coincide at a point, and have at that point different *directions*, the meeting is not called a contact, but a finite angle. When they have at their meeting the same *direction*, but different *curvatures*, it is called a contact of the FIRST order. Of this kind is the contact of one circle with another, and of a circle

---

* This does not, of course, apply to qualities of which one is only the *negation* of the other; as light and shadow, of curvature and straightness.

(or any conic section) with a straight *tangent;* for the curvature of this is 0. Contacts of this kind between two curves must be either *external,* (where their curvatures are in contrary directions, that is, one convex towards the same side that the other is concave, or one + and the other —,) or *internal,* when both are curved the same way.

But a contact of the SECOND order requires that the two lines shall, at their meeting point, coincide not only in *direction,* but in *curvature.* Hence there can be no contact of this kind between two circles, (for if their curvatures were equal and turned the same way, they would coincide altogether,) nor between any conic section and its tangent, because there is no point, in any conic section, that is destitute of curvature. But a curve that naturally has contrary flexure may form this kind of contact with a straight line drawn through its point of flexure (for at that point the curvature is 0, being at its transition from + to —.) Such contact may also be formed between two conic sections, as, for instance, between any point of an ellipse (not upon one of its axis) and its *osculatory* circle, or the circle which both touches and has equal curvature with that point of the ellipse. Contacts of the second order are neither external nor internal, but always *mixed;* the curve which is the outer one before contact, becoming the inner one afterwards.

But if the circle osculate the ellipse at the end of one of its axes, the contact is entirely exterior to the ellipse if made on its *side,* and entirely interior if made on its *end,* and in either case it is that kind of contact which we have called *internal,* one curve being within the other. This is a case of contact of the THIRD order, which consists in the two curves coinciding not only in *direction* and in *curvature,* but also in the *rate of variation* of that curvature. This rate is in the present case 0; for the curvature of the circle is unvarying, and that of the ellipse is, at these points, at its maximum or minimum, and therefore neither increasing nor decreasing, but in the act of passing from one state into the other.

So, also, when the curvatures are not only equal and varying at the same rate, but this rate of variation is also fixed in both, or varying at the same rate in both, the contact will be of the FOURTH order; and it is obvious that these orders may be extended *ad infinitum.* We may add, that all contacts of an *even* order must be *mixed*, and all those of an *odd* order must be *internal* or *external.* Hence, in so uniting two curves as to form a "line of beauty," or contrary flexure, the contact can never be of the second or any *even* order.

The abandonment in architecture, therefore, of contacts of the first order, would lead to no little complexity in the curves. Even in the simplest case,—that of the junction of a curve with a straight line, (as at the springing of an arch from its pier,—we should have to banish not only the circle, but every conic section, and use some more complex curve, such as should have a point of infinite radius (*i. e.*, of contrary flexure, if continued) at the springing. These are not only *unnecessary*, but, I will venture to say, *false* refinements. By attempting to conceal the change from one line to another, as if it were a fault, they tend to make it appear one. Now, if it be a fault, it can never be obviated in this way; for if the contact were even of the hundredth order, it would still be an abrupt change from one law of curvature to another, or to straightness. That which *must* be abrupt, is better made as perfect a contrast as possible, and not as imperfect as possible. The error has arisen from inattention to the fact that there are two kinds of contrary flexures, the one owing its beauty to GRADATION, the other to CONTRAST; that the first can only exist where there is an unbroken continuity of law,—that is, where the curve on both sides of the flexure is *one* curve; and that, whenever there are *two*, as there must be some contrast, it should be made as complete a contrast as possible, by making the contact always of the *first* order; always *external;* and the contrary curvatures, at their junction, equal.

If these views of curvilinear form be right, it will follow that all internal contacts, and all osculations (or contacts of any order above the first,) are to be excluded from ornamental design. This would condemn the Tudor arch; for in that form the change of curvature is always made by an internal contact of two circles: and though it was a capital invention for its purpose, as we shall see in a future chapter, and the best that could be expected of a school of masons who appear to have been acquainted with no curve besides the circle; yet its obstinate retention at the present day, (to the exclusion of the far more fit and perfectly graceful curve of the parabola,) only shows architecture, whether as an art or a science, to be at least three centuries behind the rest of the world.

The object of this chapter has been to consider the nature and laws of those kinds of beauty in architecture which belong to colors and to forms abstractedly; or regarded apart from the things to which they may be applied, and consequently without reference to their destinations; or to the beauties of expression, definite character, or fitness. The beauties here treated of are those to which Mr. Fergusson gives the term æsthetic, or sensuous, but it has been here attempted to be shown that this term applies, in strictness, only to the beauties of color, and that those of form are always addressed to the mind, though they constitute the lowest class of excellences so addressed ; and in as far as they make no attempt at definite expression, or the excitement of a definite emotion, do not, according to the views explained in our former chapter, entitle the art in which they are found to the appellation of a Fine Art.

CHAPTER III.

Different kinds of Beauty, of Sublimity, and of Picturesqueness—Their Characteristics.

It is the business of good taste to estimate each kind of beauty or excellence in its true relative value, so as never to

sacrifice a higher beauty to a lower, or one more nearly approaching to the merely sensual, but always the reverse.

As the merely sensuous must always give place to the intellectual, where they are incompatible; so must all the beauties mentioned in our last chapter, not merely those of color, but those of unmeaning form, gradated and contrasted curvature, give way, when necessary, to those of definite character and fitness.

The first and most obvious distinction of character in beauty of every kind, is into what may be called the bold or powerful, and the gentle or delicate styles of beauty. The bull and the stag, the oak and the palm, the rocky mountains and the swelling hills, the heroic and the pastoral poem, the Hercules and the Apollo, the painting of M. Angelo and that of Titian,—these are a few examples from the different departments of nature and art, that will illustrate the distinction here alluded to.

It is hardly possible not to observe that these two opposite kinds of beauty in visible objects are connected with two opposite qualities of outline, or rather two principles in the composion of forms. With regard to the former or more partial view of the subject, Alison says, "Simple forms, then, may be considered as described either by angular or winding lines. These different forms seem to me to be connected in our minds with very different associations, or to be expressive to us of very different qualities. I shall beg leave to mention some of these, without pretending to a complete enumeration.

"1. The greater part of those bodies in nature, which possess hardness, strength, or durability, are distinguished by angular forms. The greater part of those bodies, on the contrary, which possess weakness, fragility, or delicacy, are distinguished by winding or curvilinear forms. In the mineral kingdom, all rocks, stones, and metals, the hardest and most durable bodies we know, assume universally angular forms. In the vegetable kingdom, all strong and durable plants are,

in general, distinguished by similar forms." [He might have said *always*, in their principal or structural parts.] "The feebler and more delicate race of vegetables, on the contrary, are mostly distinguished by winding forms. In the animal kingdom, in the same manner, strong and powerful animals are generally distinguished by angular forms; feeble and delicate animals, by forms of the contrary kind." To this might be added the example of the human figure, in which, as every beginner in drawing knows, the masculine outlines are those which always present the nearest approach to angularity,—the feminine, most roundness and contrary flexures.

The same author continues—"2. In all those bodies which have a progress, or which grow and decay within our observation, the same character of form is observable. In the vegetable kingdom, the infancy or youth of plants is, in general, distinguished by winding forms. The infancy and youth of animals is, in the same manner, distinguished by winding or serpentine forms; their nature and perfect age, by forms more direct and angular. In consequence of this connexion, forms of the first kind become, in such cases, expressive to us of infancy and tenderness and delicacy; and those of the second kind, of maturity and strength and vigor.

"3. Besides these very obvious associations, it is also to be observed, that from the sense of touch, angular forms are expressive to us of roughness, sharpness, harshness; winding forms, on the contrary, of softness, smoothness, delicacy, and fineness; and this connexion is so permanent, that we immediately infer the existence of these qualities when the bodies are only perceived by the eye. There is a very strong analogy between such qualities, as perceived by the sense of touch, and certain qualities of mind, as, in all languages, such qualities are expressed by terms drawn from the perceptions of the external sense. Such forms, therefore, when presented to the eye, not only lead us to infer those material qualities which are perceived by the sense of touch, but, along with

these, to infer also those qualities of mind which from analogy are signified by such qualities of matter, and to feel from them some degree of that emotion which these dispositions of mind themselves are fitted to produce. In all languages, figurative expressions of a similar kind will be found ; and whoever attends either to his own feelings, or to the meaning which men in general annex to such words in applying them to forms, will, I believe, be convinced, that the emotion which they signify, and are intended to signify, is founded upon the associated qualities, and very different from the mere agreeable or disagreeable sensation which the material qualities alone convey.

"4. The observations which I have now made relate principally to simple curves, or to forms in which a single curvature takes place, as the curve of the weeping willow, of the young shoots of trees, of the stem of the tulip, and the lily of the valley. There is another species of form, commonly distinguished by the name of the winding or serpentine form, in which different curves take place, or in which a continued line winds into several curvatures. With this form I apprehend we have another and a very important association, I mean that of ease. From what cause this association arises, I will not now stop to inquire ; but I conceive every one must have observed, that wherever we find vegetables or any other delicate or attenuated body assume such a form, we are impressed with the conviction of its being easy, agreeable to their nature, and free from force or constraint. On the contrary, when such bodies, in the line of their progress, assume angular forms, we have a strong impression of the operation of force, of something that either prevents them from their natural direction, or that constrains them to assume an unnatural one. That winding forms are thus expressive to us of volition and ease, and angular forms of the operation of force or constraint, appears from a singular circumstance in language, viz., that, in general, all the former directions are expressed by verbs in the active voice,

—a river winds, a vine wreaths itself about the elm, a flower bends, &c.; while on the other hand, all directions of the latter kind are expressed in general by the passive voice of verbs." [The oak *is* gnarned, the river *is* suddenly deflected, the stem *is* contorted, &c.] "I believe, also, I may appeal to the observation of the reader, whether from the winding of a river, of the ivy, or of the tendrils of the vine, he has not an impression of ease, of freedom, of something agreeable to the object; and whether in the contrary forms, in such cases, he has not an impression of uneasiness from the conviction of force having been applied, or some obstacle having occurred to constrain them to assume a direction unnatural to them. In general, therefore, I apprehend that winding or serpentine forms are expressive to us of ease, and angular forms, of force or constraint."

Nature's general mode of expressing strength and the more exciting qualities being by angularity; and her general mode of expressing delicacy and the soothing qualities, by curvature; we may conclude that there must be a reason for this, —that these qualities of form must, in themselves, have a connexion with these characters and emotions of mind, independently of all association with natural objects; so that we should perceive the difference even if we had never seen natural objects. This I conceive to be the case, for the following reason: Angles are instances of the most abrupt CONTRAST between the directions of their component lines, while curves owe their beauty to GRADATION. Of these two qualities, contrast is certainly that calculated to *excite;* and gradation, that calculated to *soothe.*

If this view of the case be correct, it will follow, that all other kinds of contrast, to whatever sense addressed, will partake of the same general character of severe beauty, as angularity in form; and that gradation or modulation, wherever found, will express the gentler qualities, as well as curvature. Now let us see how this holds good in the other departments of nature and art, apart from form

And first, of light and shade; it is plain that those solids which possess straight and angular outlines will generally possess plane surfaces, meeeing in edges or nooks. Here, then, the two planes that meet at any edge or nook will rarely receive equal degrees of illumination,—often will one be in broad sunshine, and the other in its own shadow. In no case, however, whether the difference of luminosity be great or little, will there be any softening or gradation from one into the other, but always an abrupt *contrast.* Bodies of curved outline, on the other hand, will generally possess curved surface, every point of which, being differently inclined to the incident rays, receives a degree of light intermediate between that of the points on either side of it, so that the whole surface glows with continued gradations passing from the brightest point through all intermediate tints into complete shade, but without any line of division, or any contrast. Thus the same qualities of figure which most conduce to angularity of outline, conduce also to contrasts of light and shade on the surface; and those which accompany curvature of outline lead to gradated shadowing.

The simple cone, and the cylinder with flat ends, are two of the most unpleasing forms in building, (as may be seen by most of the hideous additions with which we crowd the tops of our finest buildings, because Architecture has not, since the time of the Greeks, found time to discover how to build chimneys.) This want of character in the two forms in question, I attribute to the incongruity existing between an angular outline and a modulated light and shade. The convex roofs on angular plans, common in France during the seventeenth century, are generally disliked, probably from the opposite kind of inconsistency—curvature of outline with contrasted light and shade.

Rocky scenery commonly owes its severe and grand character less to angularity of outline than to the sharply contrasted light and shade arising from the prevalence of plane surfaces and cuboidal nooks and edges. How opposite in

character is the beauty of curved undulating hills, which even when magnified to the scale of the Pyrenees, are rather beautiful than grand; and this also is due more to the shadowing than to the outline, since it is conspicuous even when the sky-line is straight, angular, or absent from the view, but can hardly be rendered in an outline drawing only.

Next, with regard to color, the great philosopher of painting says—"Grandeur of effect is produced by two different ways, which seem entirely opposed to each other. One is, by reducing the colors to little more than chiaroscuro, which was often the practice of the Bolognian schools; and the other, by making the colors very distinct and forcible, such as we see in those of Rome and Florence; but still the presiding principle of both those manners is simplicity. Certainly nothing can be more simple than monotony; and the distinct blue, red, and yellow colors, which are seen in the draperies of the Roman and Florentine schools, though they have not that kind of harmony which is produced by a variety of broken and transparent colors, have that effect of grandeur which was intended. Perhaps these distinct colors strike the mind more forcibly, from there not being any great union between them; as martial music, which is intended to rouse the nobler passions, has its effect from the sudden and strongly marked transitions from one note to another, which that style of music requires; whilst in that which is required to move the softer passions, the notes imperceptibly melt into one another."*

It may be observed that the term *broken* seems applied by painters chiefly to colors that are made, at their junction, to melt gradually one into the other, or to glow with a rainbow-like gradation of tints, the effect of supposed reflections of colored light from neighboring objects, as in the ornamental style of painting of the Venetians, of whom the same admirable critic observes, "Though in this respect the Venetians must be allowed extraordinary skill, yet even

---

* REYNOLDS, Discourse IV.

that skill, as they have employed it, will but ill correspond with the great style. Their coloring is not only too brilliant, but, I will venture to say, too harmonious to produce that solidity, steadiness, and simplicity of effect, which heroic subjects require."

The beautiful analogy, above pointed out by this master, between the forcible and gentle styles of coloring, and those of music, will convince the reader that in this latter art also, though addressed to us through a different sense, the opposite principles of contrast and gradation retain the same distinctive qualities. I doubt not that numerous passages will occur to the reader to prove that in poetry also the grander styles abound in contrasted ideas, antitheses, and truths set forth in apparent verbal contradictions ; while in the softer and more fascinating compositions, such contrasts are avoided, and the transition from one image to another is made gradually and with preparation.

We may conclude on the whole that the distinction of character between angular and curvilinear forms is only a particular case of the general distinction between things that combine order and variety by the principle of *contrast*, and those which combine them by the principle of *gradation*. It must be observed that the general neglect of this source of different expressions in abstract *form*, must be attributed to the fact that architecture is the only art to which it applies. Neither the sculptor nor the painter has to study the differences of character belonging to the differences of form, in general, but only in the particular species or class of objects which he is representing. He has to discover not what varieties of *form* most conduce to a particular expression ; but what varieties of *human form* are most associated therewith, because most frequently accompanied by the quality or emotion he would depict. His discriminations of form must doubtless be incomparably nicer than the architect requires, simply because they are all comprised within such incomparably narrower limits. Instead of being free to range

THE ERECTHEUM.

page 269.

through universal nature, not only through all existing but all possible forms, this choice is confined to the limits to which Nature has confined herself in a single species; so that, compared to the architect, he resembles a musician composing for an instrument whose range is exceedingly small ; or to a draughtsman who is prohibited the use of white or black, and confined to a limited scale of tints : of course he must compensate for this limitation of range by a more nice discrimination. But, besides this, the varieties of expression in animated forms depend on other principles than those applying to forms in general. As the chemist and physicist find the laws they have deduced from dead matter, all applicable, indeed, to living organisms, but so modified by the superaddition of new and special laws as to be sometimes hardly recognised; so we should err in applying the laws of expression, in abstract form, to imitations of living forms, whose expressions arise from associations more special, more narrow and concrete, but, at the same time, more powerful, and generally quite overpowering those which might arise from the general laws applicable to all forms alike; whence it happens, that the study of these general laws is, if not useless, at least unnecessary, to the professors of special design (painters and sculptors), and has thence fallen into neglect with the professors of abstract design (architects and decorators); but we shall endeavor hereafter to show, that only by attention to these laws have the styles which we blindly admire, miscopy, and misapply, been originated and perfected.

If it be granted, then, which I think admits of no doubt, that in all unmeaning things, (*i.e.* all those which do not affect us by association,) and in all the sensible qualities of such things, as form, shading, color, and sound, the two principles of *contrast* and *gradation* are expressive of opposite qualities—the first being grand, forcible, and exciting; the other, elegant, gentle, and soothing—it will follow, that in applying this rule to the most varied and precisely defina-

ble of the above-named properties, (that of form,) we may discriminate between the two extreme styles of form, or those which carry out the said principle to their fullest possible extent, several intermediate steps, several varieties of form, which, by approaching nearer and nearer to the simply severe, or to the merely elegant, without going to those extremes, will be fitted for various purposes, to which the extreme modes of treatment would be improper.

First, then, to decide what is the absolute extreme in the application of the principle of contrast. All curves, being instances of the contrary principle—gradation, are evidently excluded; the forms, therefore, must be composed of straight lines and angles. All angles are contrasts, but all are not equally so. The contrast between the directions of the two lines, is evidently smallest in the smallest and largest angles. On the other hand, the greatest difference that can exist between two directions, is perpendicularity. Right angles, then, present a stranger contrast than any other angles. Thus, plane figures will most powerfully carry out this principle when they are entirely rectilinear and rectangular. But in proceeding from plane figures, to the more complicated case of solid bodies, we have to consider not only the apparent outline, as seen from various points of view, but also the light and shade, which often conduces more to the general character at first sight, especially in large objects, than the outline itself. Curved surfaces, of course, are to be avoided; but what should be the prevailing angle of the edges or nooks where two planes meet? At first view it might appear that the greatest contrast of light and shade would be insured by the most *acute* arrises; the greatest possible difference of illumination being that which occurs between a plane exposed perpendicularly to the sun's rays, and the *back* of the same plane, or a parallel one. But then it must be remembered that it is impossible to see both these planes at once, and that the smaller the angle between the two planes, the smaller the chance of an eye being so situ-

ated as to see them both. On the other hand, the larger the angle the smaller the chance of the sun being so situated as to shine perpendicularly on one, without illuminating the other; and when the angle is larger than 90 degrees this will be impossible. An obtuse edge or nook, then, can never exhibit the maximum of contrast between complete light and complete shade, though every right angle and acute one *may* do so, and the more acute the more frequently will this happen, but the less frequently will it be *seen*. On the whole, then, it may be concluded (and, indeed, might easily be mathematically proved) that the greatest chance of powerful contrasts *occurring and being seen*, will be in the case of a rectangular arris.

The solid figures, then, that most completely carry out the principle of contrast, will have plane surfaces, and rectangular edges, or nooks. This is the case with most rocks, (especially the older limestones, the grandest, perhaps, of them all,) in a remarkably uniform manner. The requirements of organic bodies generally render planes and edges inapplicable ; but yet, in their outlines, we shall perceive the grander and more powerful objects, in both the vegetable and animal kingdoms, to be characterized, not only (as Alison remarked) by angles, but chiefly by *right* angles. Such are the junctions, and even chief bends, of the trunk and branches in the giants of the forest,—the oak, and the still mightier cotton tree.— How different is the effect of generally oblique junctions ; as in the elm, many pines, and most smaller trees and shrubs. In the most powerful animals, and even the most sturdy varieties of generally weaker species, the straight lines and right angles of the outline must have struck every one. In the rhinoceros, the ox, and the bull-dog, this is very obvious. There is also less curvature (or, at least, less convexity) of surface in such organisms, than in the feebler and gentler species ; for it may be remarked, that though all curved surface introduces gradation of light and shade, concavity does so to a much less extent than convexity, for the whole or great part of a concavity *may* often be thrown into equable

shadow, (as we often see in the plates of a Doric column,) while a convexity must always present soft gradation. Concavity also necessarily leads to the increase of edges, and their consequent contrasts, but convexity to their diminution. So prejudicial is smooth convexity to the kind of expression now under consideration, that nature seems to avoid or disguise it by all sorts of expedients; as rugged bark, shaggy coats, marked muscles, and the folds of the rhinoceros' hide.

Rectilinear but *oblique-angled* form may be regarded as a style one step removed from the severity and grandeur of the exclusively right-angled. It is exemplified in slate rocks, (less grand than those of limestone, notwithstanding their greater scale and primitive character,) also in the structural parts of nearly all plants not remarkable for sturdiness and durability. It may further be remarked, that the character of grandeur is always diminished, and that of elegance increased, by the introduction of *gradated systems* of lines. In the rectangular style such things can hardly exist. The only kind of gradation we can have, is that of a progressional series of dimensions; but when once oblique angles are admitted, there can be sets of lines exhibiting a gradated series, not only of dimensions, but of *directions* also. This is the case whenever they form a series of equal or regularly gradated angles, as in radiating from a centre, forming any star-like or flower-like figure, or any series of equal or regularly graduated bends, at equal or regularly graduated distances, as in a portion of a polygon, either regular, or such as might be inscribed in any curve. In fact, such arrangements will always suggest the idea of a curve, and we are affected by the expression, not only of what *exists* in any form, but also of whatever is *suggested* to the eye by it. Thus in even the most exclusively rectangular design, a step-like succession of a few zig-zags, either equal or regularly gradated, will immediately suggest the appearance of an oblique line or surface, and will therefore lose a portion of the rectangular character; and in that proportion fall off a

little from grandeur towards elegance. So also in oblique-angled design, any admission of the principle of gradation, as by fan-like, polygonal, or curve-like arrangements, will so far depart from the severe character, as to bring us close upon the verge of curvilinear design. It may be observed that whenever small, short-lived, or delicate plants are composed of straight lines, they are made to abound in these regularly gradated arrangements, either radiating or curve-suggesting. The equisetum is an instance where both are fully carried out. In the ferns also the straightness and angularity of detail (otherwise so contradictory to the graceful curvature of the general forms) is modified by the copious introduction of the principle of gradation, not indeed in *directions*, but in *dimensions*, with a degree of regularity and uniformity perhaps unparalleled.

From such examples as the equisetum, the transition to *curvilinear* design is hardly perceived. Here it is observable that those curve compositions will contain most of the principle of contrast and least of gradation, which contain most angles and fewest contrary flexures; for though the latter must perhaps be regarded (at least when composed of two curves) as extremely delicate, or infinitesimal cases of contrast, yet associations drawn from natural objects have so taught us to connect them with every thing soft, fragile, and weak, that they are, and always must be, the variety of form most removed from the severe and exciting, and most completely embodying the elegant and soothing qualities.—Accordingly it appears that the varieties of Gothic tracery in which this king of form is introduced, (as the English foliated and French flamboyant,) are always regarded as something more light, delicate, and fanciful, than the preceding varieties, which do not contain less curvature, but whose curves are united only by angles and cusps, instead of by contrary flexures.

A further distinction must still be made between *artificial* contrary flexures, or those composed of two curves, and

natural ones, or those in which the same curve (with the same equation) continues throughout. We considered this distinction in our last chapter, and may now observe that the former class (the artificial or *contrasted*) were the only "lines of beauty" known to or employed by the Gothic artists, (except of course in imitative sculpture,) and that the latter (the natural or *gradated*) were the only ones used by the Greeks, or by nature, as far as we have the means of tracing. To this class belong all the natural forms of the animal world ; as all those of the mineral belong, on the other hand, to the rectilinear and angular class.

Forms may be divided, then, as regards their inherent or essential expression, (apart from association,) into at least five classes, according to their degrees of contrast or gradation ; from the most grand, severe, and forcible, to the most elegant, fanciful, and delicate. Thus we may arrange :

I. Rectilinear and rectangular forms.
II. Rectilinear but oblique-angled forms.
III. Curvilinear forms without contrary flexures.
IV. Curvilinear forms with artificial contrary flexures.
V. Curvilinear forms with natural contrary flexures.

In most complicated productions, whether of nature or of art, we of course find several or even *all* these classes of form united. Let us inquire, then, to what differemt parts of such a composition the different classes of form are naturally and essentially best adapted.

Alison has the following correct remarks on this subject : "The great constituent parts of every building require direct and angular lines, because in such parts we require the expression of stability and strength. * * * A balustrade might with equal propriety be finished in waving lines, but certainly would not be beautiful. A twisted column, though affording very pleasant curves to the eye, is acknowledged to be less beautiful than the common and regular one. * * * It deserves to be remarked, that the form of the great constituent parts of all vegetables, whether strong or delicate, is nearly the same; the

growth of the stem and the direction of the branches being in both alike, and in both also either in straight or in angular lines. It is principally in the more delicate parts of the first, in the young shoots, and in the foliage, that they deviate from this form and assume winding or curvilinear directions.

It may be taken, then, as a principle hardly admitting of question, that, as in nature, so in art, the graver and more forcible varieties of form should in every case prevail, most in the ruling and structural parts of a work, and that the more elegant varieties should find their place chiefly in the ornamental details. In all the most approved works, of whatever style, this will be found an inviolable rule. Whether a portion only, or all of the five classes of form be employed, the class nearest the beginning of the above list will be found in the ruling forms and divisions; and that placed latest in our list will be confined to the smallest and most ornamental parts; the intermediate class or classes being found in features of an intermediate degree of importance.

In deciding to which of the five classes of form a given feature should belong, we may consider this to be dependent on three elements justly; 1st, the graver or higher character of the destination of the building; 2dly, the greater or less importance of the feature itself; and 3dly, its height above the ground. And by regarding each of these elements apart from the others, we may deduce these three rules:

I. That in buildings of different destinations, features which are of the same importance, and placed at the same heights relatively to the whole buildings to which they belong, should never be found belonging to a graver class of form in the building of the lighter destination, and *vice versa.*

II. That in the same building, and at the same height above the ground, principal and structural members should never belong to a lighter class of form than subordinate features, nor these to a lighter class than ornaments.

III. That in the same building, features of the same degree of importance, but situated at different levels, should never belong to a graver class of form at the higher level than at the lower.

These rules will, I believe, be found to apply more or less extensively both to styles and to individual buildings, in proportion as the said styles or buildings are more or less generally admired by persons of good taste. Let us examine a few instances.

In the Egyptian buildings we find forms of the first, third, and fifth classes.

In the Doric Temples rectangularity is strictly observed in the plan and principal arrangements, up to the higher part of the structure.

In the Ionic, the rectangular forms were discarded in some minor matters.

In the Corinthian Order, we have forms in the second, third and fifth kind—the fifth kind reigning exclusively in all the minor details.

In the Roman and Gothic styles, the introduction of the arch and dome constructions necessarily led to a more frequent circularity in the principal parts of buildings, both in plan and elevation, and this called for a far greater preponderance of curved forms in the minor features and details, than their servile adaptation of Grecian forms (instead of Grecian principles) would admit.

It were impossible in our brief space to seek for the principles of architectural manners that intervened between the fall of the Roman and the rise of the Gothic systems, filling up a long night of barbarism between the setting of the ancient civilization, and the appearance of the first dawning beams that heralded in the modern.

As the lighter classes of form are indisputably the most beautiful in themselves, apart from fitness, there is generally, when the art is in a progressive state, far more danger of their encroaching on the domains of the graver classes, than

there is of the contrary evil. Accordingly, it was in this way that the Greek, the Gothic, and the Italian systems all declined and fell after their perfection had been reached, and change began to be sought no longer for the sake of improvement, but for the sake of change. To these we might add the Moorish system, which seems to have culminated in the Alhambra, and afterwards to have sunk under this same abuse—the fourth class of forms gradually superseding the third, even in so important a member as the arch. The great defect of this style, however, was always want of attention to this correct placing of the different classes of forms; and at present, in the poor remains of it practised in Mahommedan countries, the forms are jumbled together with as little regard to fitness, as in our own sham architecture. If we may judge from engravings, the arches are almost exclusively of the reflexed (or ogee) form, while mere details on them are often of a more severe class (the second), and the minutest lattice-work often of the first. The confusion, however, cannot be worse than that to which our own building is reduced, in which the gravest forms are often piled on the top, if indeed there be any top—architecture having generally been driven from thence—and clothing only the sides to a certain height, leaving all above to the ventilator and chimney-doctor.

It is now necessary to say a few words on two qualities in architecture and other arts, frequently distinguished from the beautiful, though at other times classed as particular divisions thereof: these are the *sublime* and the *picturesque*.

The inquiry into the sources of the sublime in architecture must on no account be passed over by the architect, as having no application to his every-day practice; for the same principles by which sublimity has been produced in great works, are the only ones by which the opposite of this quality can be avoided in small works; and, indeed, this opposite (viz., *meanness*) is the very worst fault a building can have, and its avoidance is, if possible, more important in

little works, than is the attainment of true sublimity in great ones; for magnitude and richness will, with the many, always suffice to cover the want of the latter; while nothing can, in small buildings, stand in the stead of that for which we have no good name, but which would, if increased in scale, be called sublimity.

We conclude that the *forms or arrangements of form* used in the Doric order, are better suited to produce sublime effects.

No Gothic building ever possessed a particle of sublimity, unless at least doubling the extent, and trebling the height, of an ordinary Doric temple.

This superior sublimity of square-headed openings and recesses arises not only from their belonging to a graver class of form than the arch, but also, very often, from their greater expression of *power*, owing to our knowledge, or mechanical perception, that they *must* require larger stones in their construction. This somewhat vulgar consideration has, I am convinced, a great deal more to do with our appreciation of sublimity in architecture than we should be willing to admit. Thus, the original Doric cornice has very little projection compared with later forms of that feature, yet it produces as grand an effect as many cornices that have three times its projection. This arises from the absence of all contrivances for supporting it by corbelling,—from our perception that it cannot possibly be built up of little pieces. Add such contrivances, (as in the Corinthian cornice, or still more obviously in the Gothic machicolations;) and you must increase the frowning mass to several times its dimensions, in order to retain the same bold and noble appearance. So, also, the relative effect of square and of arched coverings above alluded to, is entirely reversed in Gothic architecture. Here, the arched window-head, when sufficiently recessed and overhanging, has some grandeur, while the flat-topped Tudor form has not a particle; being propped up, and, as it were, balanced on the mullions, whose apparent insufficiency

for its support only increases the intense *meanness* of expression.

Next to the prevalence of the graver classes of form, and the subordination of the others to them, nothing is more essential to nobleness, than a principle analogous to what painters term *breadth, i. e.*, abundance of one thing in one place. On this subject, Ruskin has insisted with his usual eloquence,* and, with great truth, says, "that the relative majesty of buildings depends more on the weight and vigor of their masses than on any other attribute of their design; mass of everything, of bulk, of light, of darkness, of color, not mere sum of any of these but breadth of them; not broken light nor scattered darkness, nor divided weight, but solid stone, broad sunshine, starless shade."

On the whole, it would appear that neither sublimity nor satisfactory beauty in building, can be expected of a flat surface with holes in it, however beautiful their forms and arrangement. There must be variety and contrast of surfaces, and large ones too. There is no such thing as fine architecture of only two dimensions; it must have length, breadth, and depth. No building has ever been admired that has not either colonnades, or arcades, or very prominent buttresses, or a very prominent cornice, or very deeply recessed openings. These are the chief means that have hitherto been employed to obviate flatness (though never for that purpose *alone*) in permanent buildings. In temporary ones there have been some other expedients, as the broad eaves of Italy and Switzerland, the overhanging stories of our half-timbered houses, and the verge-boards, best developed, perhaps, in northern France. When iron shall be admitted into architecture, perhaps a new resource of this kind may be found in balconies or window-canopies, or both: but, as a general rule, all horizontal masses of shadow seem to require a greater and general mass of the same kind at the top of the building; and this is the most general feature in

* "The Seven Lamps of Architecture," chap. III. "Power."

all countries, and is never, in any degree, a merely ornamental one, since its use, to shelter the walls, will always be more effectually served the more it projects: not an inch added to it can ever be useless.

Another mode of avoiding flatness has, indeed, been often practised in rural buildings, (being inapplicable in towns,) and consists in breaking the ground plan in a complicated manner, and carrying up some parts higher than others. It has a very specious appearance of effecting the object without unnecessary expense; but this is a great fallacy, as any one may soon see, who makes a few calculations, that these breaks and jetties add more to the material requisite to enclose and cover a given space, and, in fact, are a greater sacrifice to architectural beauty, than the largest features ever added to such buildings, supposing them added for ornament alone, which they never ought to be. When fashion, however, runs mad after some style devoid of prominent features, (as the Tudor,) there is no alternative but this extravagant broken-plan system, as the late Tudor revivers found to their cost.

Of that most highly artificial source of pleasure, called the *picturesque*, there have been several explanations given, all in substance the same as that of Ruskin, who regards it as a "*parasitical sublimity*," or a display, in the extraneous and adventitious circumstances of a thing, of such qualities, as, transferred to the thing itself, would conduce to sublimity: thus the same shagginess which in the lion's mane conduces to sublimity, in the goat constitutes picturesqueness. The same depth, and prevalence of contrast, in a building, which, when produced by evident *design*, leads to nobleness, or at least obviates meanness; when resulting from *chance*, (either by the falling of a building to ruin, or the unforeseen clustering of several buildings together,) constitutes the picturesque. The chance combinations, which, in natural scenery on a small scale, are most picturesque, are the very same which, if magnified to a mountainous scale, would

be the most sublime; so that an artist might often from heaps of gravel or mortar, compose scenes more awful than he could find in a year's wandering among Alps. Again, the picturesque in painting, or what is called "pictorial effect," consists in applying to the adventitious circumstances of light and shade those same principles and rules which the higher aims of the art would require to be observed with regard to things and actions themselves; so that, for instance, pictorial effect requires one principal light, just as the higher excellences would require one principal action. Whatever would be sublime or excellent in *essentials*, the same is picturesque in *non-essentials*. "There are thus," says this writer, "both in sculpture and painting, two, in some sort, opposite schools, of which the one follows for its subject the essential forms of things, and the other the accidental lights and shades upon them. There are various degrees of their contrariety: middle steps—as in the works of Coreggio, and all degrees of nobility and of degradation in their several manners; but the one is always recognized as the pure, and the other as the picturesque school."*

It would thus appear that this quality has more affinity with the sublime than with the beautiful, being probably incompatible with the latter in its strict sense, while each of these opposite qualities is compatible with the sublime, at least with what may be called *physical* sublimity, which is the only kind of which we have hitherto spoken.

Consistently with this, we might expect the picturesque in building to be most frequent where there is most prevalence of contrast, and the gravest or most contrasted species of forms; and perhaps the best rule that could be given for its production would be the accumulation of all the physical elements above mentioned as conducing to sublimity, with a studied exclusion of those previously described as belonging to beauty, such as uniformity of halves, equidistant repetition, and the principle of gradation in general.

* "The Seven Lamps of Architecture," chap. vi.

We have already observed that in forms, or rather compositions of form, of the first two (or rectilinear) classes, a distinction must be made between those which do, and those which do not, display this principle of gradation; which can occur in the first class only in one way, by a gradated series of *dimensions*, while in the second it may be displayed in two ways, either by gradation of dimensions, or of *directions (i. e.,* of lines or of angles.) The influence of gradated dimensions, in diminishing grandeur and increasing elegance, may be seen by comparing the majority of Italian campaniles (which contain no such gradation) with those of Pisa, Cremona, or St. Bride's, London, [the only one of Wren's designs in which this principle reigns,] or with the Chinese towers, in which it seems universally observed, and contributes not a little to their want of grandeur or solemnity. In the grander and more sturdy classes of vegetables, too, from the cotton tree down to the thorn bush, this principle is nowhere to be found; while in those few plants of the minor and less durable kind, that contain straight and angular forms, it is carried to extreme perfection, as in the grasses, ferns, &c. It seems as if this elegance were given them as a snbstitute for that of curvature, common to other delicate vegetable forms.

Now neither these plants, nor the gradated campaniles, would ever be regarded in themselves as picturesque objects, while the first-mentioned class of each is reckoned among the most decided examples of this quality in nature and in art. The beauty of gradation, therefore, while it is only prejudicial to real sublimity, is *destructive* of this sort of "parasitical sublimity," called the picturesque. Divisions, when not equal, must be varied without any connecting law, as in fig. 1 A, never as in C and D. To show how much a prevalence of the lighter [or more gradated] classes of form also militates against the picturesque, we may observe that this quality was perhaps never ascribed to any natural object whose forms are exclusively curvilinear; and that it is rare

in [even the ruins of] round-arched building; more frequent in the pointed; and most of all in those styles which are destitute of arches. The Egyptians often clustered buildings irregularly to suit peculiar sites; and the temple thus built on the island of Philæ has been instanced as a very complete case of picturesqueness, and will illustrate the rules given above.

CHAPTER IV.

Imitation of Nature and of Models—False Imitation—Constructive Truth—Constructive Unity—Three Systems thereof.

It is the highest possible aim of architecture, as of all the other fine arts, to *imitate nature.* This has been generally admitted; but the kind of nature to be imitated, and the mode of imitation, seem to be very variously understood; and the notions of some architectural writers on this point are singularly different from each other, and from the plain, ordinary sense of the expression.

The difference between copying natural objects and imitating nature, lies in the introduction, in the latter case, of a principle of *generalization.* To draw the likeness of a particular man, ever so exactly, though you excelled the daguerreotype, is not imitating nature. To discover and draw *all that is common* to a certain class of men, omitting every thing *that is peculiar* to each, this is imitating nature. The same principle must run through every imitation of her, as distinguished from an imitation of a natural object; and it must be remembered, that with this latter imitation, architecture has nothing to do. A man may learn to paint or carve, simply by imitating individual models, and may with the vulgar pass for an artist: but in architecture, there is no such thing as this copying of one thing at a time: the architect [I mean the *designer* in architecture] must learn to copy several things *at once,*—to imitate with generalization.

Here is an example: We want a column, that is, a long body, intended for transmitting pressure to or from a flat surface. It evidently matters not whether the column be pressed against the surface or the surface against it, nor in what position it be placed. A strut is a column, only placed horizontally or inclined. The expression we want to give is that of fitness to receive this pressure. Some nations have copied columns from trees, and some from men, but neither of these are imitating nature; on the contrary, they are most unnatural, since nature has not made either a tree or a man to serve the purpose of a column. Are there, then, no columns in nature? Certainly there are. The limbs of all animals are columns according to the above definition, the surface against which they press being the ground. The human arm uplifted to support a weight is also a column; and when pushing horizontally against a wall, it is a horizontal column or strut.

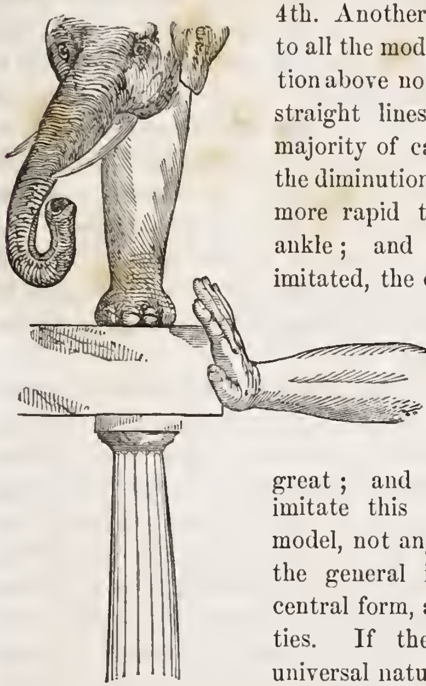
Now, in comparing these various natural columns, to discover what they have in common, we find

1st. That their transverse section has *roundness*, therefore we make the artificial column round.

2d. We observe that they vary in length from *four* to *ten* times their greatest diameter; but that, in animals remarkable for power and majesty, they do not exceed *six* times the said diameter. Therefore, when this character is aimed at the columns are confined to a length of between four and six diameters.

3d. With regard to their longitudinal outline or profile, they have a general diminution from their origin to the ankle or wrist, *i. e.* to a point *near* the surface against which they are applied. Therefore we make the artificial column diminish from its origin (the ground or stylobate) to a point near the surface to be sustained. This 'diminution is in a contrary direction to that of the legs of animals or furniture, because *they* issue from the object to which they belong, and apply themselves against a surface below; but the legs of a *fixed*

structure should issue from the substructure, and apply themselves to the support of that above ; otherwise they would appear to belong to the superstructure and form with it one mass, distinct from that below, and made to be moved about like a table.* The *position*, therefore, of the column, is not that of the leg, but that of the uplifted arm.



4th. Another circumstance common to all the models, is that the diminution above noticed, is not regular or straight lines, but tends, in the majority of cases, to convexity, *i. e.* the diminution, at first slow, becomes more rapid towards the wrist or ankle; and this is accordingly imitated, the convexity (or entasis) being, however, much less than in the human example, because in that example it is peculiarly great ; and the object is not to imitate this or any other *single* model, not any particular limb, but the general idea of limbs—their central form, avoiding all peculiarities. If their outline were, in universal nature, as frequently concave as convex, the correct imitation would be to make it straight ; but this is not the case,—convexity predominates over concavity, and *very slight* convexity predominates over that which is more decided.

* An eminent architect has attempted to explain this, by asserting as a rule, that bodies must diminish as they *recede from the eye*, as a column upwards, or the leg of a table downwards. He does not give any reason or foundation in nature for this rule ; but it would be very desirable to do so, as it would overturn many long-established prejudices in architecture, and lead to some curious novelties, such as the downward diminution of balusters, pedestals, &c.

5th. We observe it to be a part of the nature of limbs, that, after passing the smallest part, there is a rapid swelling to form the extremity (hand or paw), which is what, in the column, we call its *capital.* This protuberance is, in nature, commonly eccentric with regard to the axis of the limb, projecting most on the side towards which the animal looks, and least (or often not at all) on the opposite side. But this eccentricity is least in the most powerful animals, and is properly omitted in the column for two reasons ; either as an exaggeration of that which distinguishes the most powerful models, *i. e.* those most displaying a quality intended here to be expressed ; or else it is omitted as having an obvious relation to a property *not* intended to be expressed, viz., locomotion : for the foot always projects most on the side towards which it is to move ; and as the capital is not to move, there is no natural example for its projecting on one side more than another.

6th. With regard to the outline of the extremity, we find it to be at first concave for a very short distance, then becoming very slightly convex, and as it spreads, the convexity slowly increases, till, at the greatest protuberance from the axis, it rapidly curves round, and returns inward to a small distance. Such are the points common to the outline of *every* animal extremity, when applied against a flat surface; and such are those which constitute the profile of the capital, in that wonderful specimen of generalized imitation, the original Doric column; that form on which no subsequent efforts have been able to effect any improvement in fitness of expression to its particular purpose; that form which when first seen, so throws into the shade everything else that we have ever seen applied to the same purpose, that it seems too perfect for a human invention, and we attribute it to some power peculiar to the inventors, and now lost, just as the Arabs attribute Palmyra to the work of genii. That this pile of cut stones, which any mason could exactly reproduce, and which resembles no natural form, should yet

express its destination as perfectly as the most finished statue, and appear as incomplete without its entabulature, as Atlas without his globe ;—that this effect should be produced alike and instantly on every spectator, may well appear, to the untaught, a sort of magic. But such effects are never the result, as commonly supposed, of a happy idea, an instant stroke of genius : they thus touch in an instant, because they contain the work of years ; they spring from, and are proportional to, the *amount of thought* which the object embodies, and this is independent altogether of the amount of manual labor bestowed. A work of elaborate sculpture, and one of mere masonry, may be exactly equal in this respect ; and when either of them strikes us with this instant conviction of excellence, it is because they contain, as it were, concentrated in them, the thought perhaps of a life, perhaps of many lives, the observation and analysis and intense patient study of *many,* directed all in one direction, and with a common object,—the extraction and purification of some general idea in nature, as a metal is extracted by the chemist.

In the study of nature (without which the architect as well as every other artist can do nothing—absolutely nothing) he must also study the commentaries on her, *i. e.*, all previous productions of his art. All these are so many annotations on Nature's great and most difficult book ; and he who attempts to read her without their assistance, simply sets up his own wisdom against that of all mankind ; and however satisfactory his discoveries may be to himself, he may be assured that they are as old as Adam ; and that, should he have at once the greatest genius and the longest life ever granted, he will still have advanced no further than the first efforts of the art, which, pursued on this principle, would (unlike all other human pursuits) be never beyond its beginning.

It is impossible for the designer to produce anything *true* but by the study of nature, and it is impossible to produce anything *new* but by a knowledge of what has been done al-

ready by his predecessors. The most *original* artists of every kind are always the most extensive imitators.

In architecture the number of such is indeed infinite: and while one appears to have seen no building besides the Temple of Ilyssus; another, nothing but the Erechtheum, or Salisbury Cathedral, or Henry the Seventh's Chapel, or the Alhambra; all unite in condemning that architect in the last century who drew from no source but Diocletian's palace, without perceiving that they are committing the very same capital error; for the fundamental fault was not the drawing from a *corrupt* source, but the drawing from *only one* source.

The reader must not suppose I am advising any thing so utterly wrong and contemptible as the *mixture of the peculiarities* of different styles. On the contrary, I am insisting on the imitation of what is common to them, rather than that of what distinguishes each. If you say "there is nothing common to them but walls and a roof," you betray that you have not commenced the real study of the art, which, like that of nature or of science, can be carried on only by generalization.

As in all other arts, so in architecture, the value and correctness of imitation, whether of Nature directly, or of Nature through the medium of her interpreters,—previous artists,—depends entirely on the breadth of generalization accompanying it; and that which simply imitates without generalizing,—that which imitates only one model, though even a natural one, and ever so excellent, is not art at all.

Connected with the error that imitative art consists in the imitation of what is commonly called nature, *i. e.*, of particular or individual nature, is also the most destructive notion that its perfection is to "deceive the eye," which is, in fact, the basest purpose to which any art, or rather any skill and science originally amassed for the purposes of art, can be prostituted: for it must be observed, that no manual dexterity can be called art; it is only the material collected for its

use, or the language in which it speaks. Now, when this is used in order to deceive in any way, it is as if a man, who had learned writing in order to write sermons, should employ his skill in commiting forgery.

"For want of this distinction," says Sir Joshua, (*i. e.*, the distinction between the art and the mechanical skill,) "the world is filled with false criticism. Raffaelle is praised for naturalness and deception, which he certainly has not accomplished, and as certainly never intended." It is the same error which leads the vulgar to think it a beauty when the figures of a picture stand out "as if you could walk round them," or when painted decorations, or papering, or carpets, are shaded to appear [in a particular light] as if carved; or when a building, or a front of a building, or any of the smallest part or member thereof, appears like any thing which it is not;—a new building like an old one built in a different age; several little houses like one palace; or one property like several; an essential part like an ornament, or an ornament like an essential part; a buttress like a column, an attic like a pediment, an arch like a lintel;—to say nothing of such gross frauds as making stucco look like stone, or paint like wood.

The object of all real art, as of all science, is to elicit TRUTH; but any one who, fresh from nature, or from the works of other ages or nations, should arrive among the works of modern English architecture, would suppose its whole aim, and that of every detail in it, to be DECEPTION. One enters a building, perhaps a place of worship, that is praised for *unpretending plainness*, and the eye seeks in vain for a single object on which it can rest as something real,—for a single feature that is what it appears to be. The plastered walls pretend to be built of huge granite or marble blocks; the flimsy surface that conceals the roof, to be composed of lacunariæ, or stone coffer-work, on a more colossal scale than any Egyptian ever dreamt of. A stove must represent an useless pedestal, or, perhaps, the model of a build-

ing ; and the deal fittings, not content with one deception, must with singular ingenuity contrive to perpetrate two at once,—to appear in *substance* like oak, and in *form* like the marble walls and antæ of a Greek temple. Such is an *unpretending* building. The evil so infests everything that meets us on whatever side we turn, that it is hardly possible to realize the fact, till we turn to the works of other ages or distant nations, that *all this is unnecessary*, that there may be, and over most of the world *is*, and every where *has been*, architecture WITHOUT DECEPTION,—not without this or that kind of it, but absolutely without ANY. Such is the atmosphere of it in which we are plunged, that we can hardly fancy such a thing as its absence ; and we actually, on mentioning it, are met by such questions from intelligent and otherwise well-informed persons, as " What is the use of paint, if not to imitate other things ?" Grown-up men actually require to be told that paint is a durable and smooth coating for perishable or rough surfaces, either to preserve them, or by its smoothness repel dirt, or to replace their natural color by one more pleasing or fitter for their situation ; or lastly, to adorn their surface by varied color or beautiful forms. These are the uses of paint, and they give vast scopes for design and taste, but have no more to do with imitation or deception than the skin of an animal or plant has. Does the skin or bark imitate flesh or wood ? What possible reason then can there be for stucco or paint to represent anything but stucco or paint ? They never represent anything else in the works of the Greeks, Romans, Gothicists, or Arabs ; and when we want *more* ornament than is found in their works, it will be time enough to look for a method not practised by them.

Ruskin, who, though falling into my dangerous fallacies, has truly treated on this subject, says—" It is very necessary in the outset to mark clearly wherein consists the essence of fallacy as distinguished from supposition : for it might be at first thought that the whole kingdom of imagination was one of deception also. Not so : the action of imagination is a

voluntary summoning of the conceptions of things absent or impossible ; and the pleasure and nobility of the imagination partly consists in its knowledge and contemplation of them as such, *i, e.*, in the knowledge of their actual absence or impossibility at the moment of their apparent presence or reality. When the imagination deceives, it becomes madness. It is a noble faculty so long as it confesses its own ideality ; when it ceases to confess this, it is insanity. All the difference lies in the fact of the confession, in there being *no* deception It is necessary to our rank as spiritual creatures that we should be able to invent and to behold what is not ; and to our rank as moral creatures, that we should know and confess at the same time that it is not.

" Again, it might be thought, and has been thought, that the whole art of painting is nothing else than an endeavor to deceive. Not so: it is, on the contrary, a statement of certain facts in the clearest possible way. I desire to give an account of a mountain or of a rock: I begin by telling its shape; but words will not do this distinctly, and I draw its shape, and say, "This was its shape." Next, I would fain represent its color: but words will not do this either, and I dye the paper, and say, "This was its color." Such a process may be carried on until the scene appears to exist, and a high pleasure may be taken in its apparent existence. This is a communicated act of imagination, but no lie: the lie can consist only in an *assertion* of its existence, [which is never for one instant made, implied, or believed,] or else in false statements of forms or colors [which are indeed made and believed to our great loss continually.] And observe also, that so degrading a thing is deception, in even the approach and appearance of it, that all painting which even reaches the mark of apparent realization, is degraded in so doing. * * * * * * * *

" The violations of truth which dishonor poetry and painting are thus, for the most part, confined to the treatment of their subjects : but in architecture, another and a less subtle,

more contemptible violation of truth, is possible ; a direct falsity of assertion respecting the nature of material, &c. ; * * and this is, in the fullest sense of the word, wrong ; it is as truly deserving of reprobation as any other moral delinquency ; it is unworthy alike of architects and of nations ; and it has been a sign, wherever it has widely and with toleration existed, of a singular debasement of the arts : that it is not a sign of worse than this, of a general want of severe probity, can be accounted for only by our knowledge of the strange separation which has for some centuries existed between the arts and all other subjects of human intellect, as matters of conscience. This withdrawal of conscientiousness from among the faculties concerned with art, while it has *destroyed the arts themselves*, has also rendered nugatory the evidence which otherwise they might have presented respecting the character of the respective nations among whom they have been cultivated ; otherwise it might appear strange that a nation so distinguished for its general uprightness and faith as the English, should admit in their architecture more of pretence, concealment, and deceit, than any other of this or past time."—" *Seven Lamps of Architecture*," II. " *Truth*."

It will be asked, perhaps, " Must we not turn the best side, outwards, then ?" Certainly, this is an important part of the courtesy of building. It is a mark of respect due to all who see your work, to turn them its best side ; but it is still more important to do so honestly,—to proclaim at the same time " This is my best side." Herein consists the whole difference between the incrustations of mean materials with richer ones, practised in times and places of good taste, and in those of bad. The covering of a poor or unsightly material with a better, does not necessarily lead to deception, or any thing of the sort. Many churches in Italy are said to be *veneered* with marble ; that is, thin slabs of marble are let in and confined by surrounding bands of stone, as the metopes of a Doric temple by the triglyphs, or as panels are confined in

joinery. There is no deception, the whole shows plainly what it is,—a sound piece of construction held together not by cement, but by obvious mechanical arrangement; and the marble slabs pretend to be nothing more than slabs,—beautiful natural objects placed there for ornament or cleanliness, and not for deception.

When an external film is of a totally different nature from the substance beneath, the form will often inform us that this external substance cannot be that of which the whole is composed, and thus there will be no deception. This is the reason that *gilding is no deception* when not applied to metals. We can no more mistake a gilded stone or plaster ornament for one of gold, than a stone-colored metallic object for one of stone, because the peculiar mechanical properties of a malleable metal would prevent its ever being made into the same form as stone or plaster (unless for deception). Metals, woods, and brittle materials are known from each other, independently of color, by the three characters of form to which their respective properties lead. Hence gilding can never deceive *except upon metals;* and upon these we shall accordingly never find it applied in times of good taste,—at least, never as a *total* covering.

In colored *decoration* on flat surfaces, all shadowing (*i. e.*, representation of the effect of solidity and relief) is a direct falsehood, whether it deceive or not. But observe the difference between *decoration* and *picture.* A picture (whether with or without background) is *one thing*, an independent whole, distinct from all surrounding things, and therefore requiring to be separated from them by a frame or border (either painted or in relief); but *whatever has no frame is no picture;* it is *decoration*, and comes under a different principle of design altogether, being not a *whole* but a *part.* Now, decoration is of two kinds, consisting either of forms in relief, or of colors on the flat; but the latter is given up, and loses its separate existence if it attempt to ape the former; we have no longer two kinds of decoration, but only one,

viz. carving and sham-carving. But you say, the flowers are ugly without shading, and that if they are imitated at all, why may not their shades be imitated? Here we come to the root of the whole fallacy. *You have no business with imitated flowers*, in the vulgar acceptation of *imitated*, i. e., *copied* ones. Their place is in picture, not decoration. No natural flower is fit or beautiful in decoration; if it were, it would not be fit or beautiful in nature. The notion, at present very common, that natural (*i. e.*, particular) flowers should be imitated in decoration, is most false and *unnatural.* No one thing in nature is natural enough for decorative use. This art, like architecture, must generalize,—must copy not a natural form, but a natural idea. Its flowers are as false, when copied from single natural models, as columns would be if copied from a single natural limb. In the whole of the works of those who used the *most* ornament, and (by universal consent) the *best*, viz., the Greeks, Romans, Gothicists, and Arabs, we may challenge the production of *one* example (except in times of acknowledged debasement) of what are called natural flowers, that is, *sham* flowers.

If you say shadowings produce boldness and (if properly treated) *breadth* of effect, so do masses of dark colors, without deception, equally well; for proof of which, you are referred to ALL the designs of the above schools, without exception. Decorative designers seem to produce few *forms* not drawn from those exhaustless sources: it is to be wished they would copy some of their *principles.*

Much stir has been made, of late, about our inferiority, in all matter of taste, to neighboring nations, who, however, are rapidly descending to our level; but this stir is utterly vain among a people with whom *art* means *deceit.* Until we can be taught that nothing is beautiful which is not TRUE, we shall find taste a jewel beyond the reach of all the nation's wealth to buy, and of all her power to win.

Sometimes the truth of particular numbers must be sacrificed to that of the whole, as in Gothic architecture of

the purest kind ; in which the smallest coverings or heads to openings, though not constructed on the arch principle, are nevertheless made to resemble arches, in order to carry out the chief *general truth* of that style, which is *arcuation*, or the exclusive use of this mode of covering openings and spaces.

Constructive Truth and Constructive Unity are the two most important principles to be borne in mind, in tracing the history of architecture, and are indispensable in any attempt to rival, or even understand, the productions of the two standard or perfected systems which the world has hitherto seen,—the Greek, and that commonly called the Gothic.

Constructive Truth requires that a building shall never appear to be constructed on different statical principles from those really employed in its construction. *The whole of modern Gothic architecture is a constructive falsehood*, because it will presently be shown that all the peculiarities of this style grew from the practice of constructing, within buildings, a vaulted ceiling of stone, and were solely adapted to a building with such a ceiling. Consequently, when applied to a building not so ceiled, the style must either be made useless and meaningless, by copying only its forms without a motive; or else, if correctly copied *(i. e.*, preserving the apparent motive, either externally or internally, or both*)*, it must then appear *(*either externally or internally, or both*)* to have a vaulted ceiling, which it has not ; and, in either case, the whole must be a lie from the foundation to the finials.

Constructive Unity is a principle no less important than any other unity, and bears an especial analogy to *unity of style*, being in fact the same thing in construction as the latter in decoration. I assume that no one disputes the necessity of an uniform style of ornament throughout the same building. Now, construction is a more important thing than ornament, and has more relation to the higher excellences of the art. Architectural beauty is not mere beauty of *form*, mere eumorphy; if it were so, a beautiful form would be beautiful wherever exhibited, in a pepper-box or a tower,

a baluster or a column. In all the more important features [indeed all but the merest ornaments,] the beauty of abstract form is to be sacrificed to that of statical fitness; but in order that this may be seen or appreciated, it is necessary that the various *pressures* be perceived, or a part of them, to which part the members may be seen to be fitted. Consequently, if it be necessary that the treatment of geometrical *forms* be consistent throughout, it is far more necessary that the treatment of these *pressure*, or of the displayed portions of them, be consistent throughout.

Now, there are three distinct modes of treating the pressures of a building ; or, in other words, three *styles of construction.* They are all mixed indiscriminately in every modern building; but it is the peculiar merit of the two hitherto perfected architectural systems, the Greek and the Gothic, that in the pure examples of each, only *one* of these modes of construction was seen. This is what distinguishes those two styles from all others, and the pure period of each from preceding and following periods,—*constructive unity.*

Perhaps I should rather call it *unity of statical design ;* for the actual construction has never, except in Egypt, been absolutely pure throughout : but a portion of the construction is unavoidably hidden in every artificial structure, as it is even in every natural one.

The three styles of statical design were well pointed out in the very useful work of the late A. Bartholomew.* They depend on the three modes of applying force to solids, by *cross-strain,* by *compression,* by *tension* These are, of course, familiar to the reader who has looked into the rudiments of constructive science, to be found in several of the volumes of this series.

The first and simplest mode of construction, that employed by all barbarous and infant nations, is the only one which subjects materials to *cross-strain,* the most wasteful mode of employing their strength. The method, however, may per-

* "Specifications for Practical Architecture," &c.

haps be described in the most general terms as that of *vertical pressure*, because all the pressures throughout the building are wholly in their natural direction, vertically downwards; and for this purpose all the continuous joints, or beds, throughout the structure are made *horizontal*, and all the interrupted joints *vertical*. All openings are covered without any deviation from this rule, by laying a beam, lintel, or architrave across from pillar to pillar, resting on the flat tops of both; and all ceilings, whether in stone or wood, are formed by an extension of the same method: the roof framing, being concealed both from the exterior and interior, forms no part of the design, and by the Greeks it was probably constructed on the third method—that of tension.

During the prevalence of this first constructive style in its purity, *every oblique pressure* was excluded, as contrary to the principles of sound architecture. The introduction into architecture, however, by the Etruscans and Romans, of the new constructions called the *dome*, *arch*, and *vault*, all depending on oblique pressure, gradually destroyed the consistency of this first architectural system, the forms of which, owing to the intrinsic beauty imparted to them by the Greek genius, were not readily abandoned, but continued to linger on, though more and more debased in geometric beauty, and forming harsher and harsher incongruities with the new constructions, till, in the eleventh and twelfth centuries, the great extent of church building, and the desire to render these structures fire-proof, led to the extension of the arch principle to the covering of ALL openings, and the ceiling of ALL areas, and from that moment architecture took a new turn. From the *invention of the arch* till the *rejection of the beam* (a period of about fifteen centuries,) every change had been for the worse; the whole history of the art was *debasement*, from the progressive loss of constructive consistency. *The beam was rejected*, (at least in north-western Europe,) and immediately all was *purification* and rapid return to unity.

The forms derived from Greece, but by this time so decrepit as to retain little vestige of their original beauty, were now gradually abandoned, and everything old (except first principles) sacrificed to the new idea; and so rapid was the progress, that by the year 1250 in Germany, and by 1300 in England, the unity of the new system was established: and now let us see in what consisted this unity.

The second system of statical design consisted in the complete avoidance of *cross-strain*, and in the subjecting of the materials throughout the whole of the visible construction to forces of *compression alone.* It may therefore perhaps be best termed the *Compressile System.* In order to effect this, the pressures can no longer be every where vertical; and as it is a most important point in construction that the continuous joints, or beds, should be as nearly as possible perpendicular to the pressures acting on them, these joints are no longer universally horizontal, but inclined in various directions, and should have been so to a greater extent than the Gothicists practised. Indeed, there would be much room for the improvement of that system by the introduction both of modern science and of a larger portion of Greek taste (of which it nevertheless retained a good deal in its best productions.)* But imperfectly as the Gothic aim was carried out in construction, and often also in decoration, it was completely accomplished in statical design, *i. e.*, throughout the *visible* construction there was no portion of matter subjected, as far as the eye could judge, to any other force than simple compression. When this is the case [and not otherwise] a building may be termed completely Gothic; being complete in its statical design. The geometrical design is another point, quite independent of this, and is reducible mainly to the correct positing and subordination of the five classes of forms mentioned in our last chapter; a principle *equally necessary in every style.* A building may be perfect in its statical design,

* Of course I do not mean Greek *forms*, the emancipation from which had been an essential part of the formation of the new system.

while it is extremely faulty in the geometrical, as was the case with nearly all the buildings of Egypt.

The Gothicists, like the Greeks, employed a tensile construction in the roof framing, that being in both systems invisible either from the exterior or interior. Nor was this concealment any defect; for, as Ruskin has observed, "the architect is not *bound* to exhibit construction:" still less can he be bound to exhibit the *whole* of it, to do what nature has never done. He may conceal as much as he likes, but may not *disguise* any. None need appear, but that which *does* appear must be *true*.

After its culmination, the Gothic system gradually declined, from the progress of a variety of falsehoods, of which some were general to the whole of the countries in which it flourished; others confined to France or Germany, or England, or the Netherlands. It is not the place to enumerate them here, but to observe that one of the chief causes, especially in England, was the superseding of stone by timber in many parts, particularly ceilings, and the consequent extension of the style of construction best adapted to this material, which is the third style already twice alluded to, viz., the *tensile*.

In the compressile system, all apertures and spaces were covered on the arch principle, and the oblique pressures thus occasioned were transmitted down to the ground by masses of material called *buttresses* or *abutments*. But this is not the most economical mode of treating the said pressures when we have materials of great length and strong *in tension*, as timber and iron. The more obvious and less wasteful mode is tying the two feet of the arch together by a bar of one of these materials, thereby counteracting the horizontal portion of the oblique pressures, and leaving only their vertical portion to press on the two supports, as the original beam or lintel of the first style did, and render all buttressing from without unnecessary. Instead of the arch, an arrangement of two or more bars or timbers may be substituted, and thus

arise the various kinds of *truss*, whose perfection consists in having no part subjected to cross-strain, but every part either to direct compression or direct tension.

This third constructive system combines, in a certain degree, the advantages, and avoids the defects, of both the others: for all its *active* pressures are vertical, as in the *first* style; and yet it avoids all cross-strain, like the *second*. It saves all the waste of material [not conducive to strength] in the *lintels* of the former style, and, also, *all* the material of the *buttresses* in the latter.

But, though there are three styles of construction, there have been only two systems of architecture,—only two styles possessing *constructive unity*—the Greek and the Gothic. The third constructive principle has yet to be elaborated into a system. The two systems are past and dead; we may admire the fading vestiges of their loveliness, but can *never* revive them. The third is the destined architecture of the future.

CHAPTER V.

Application of the Foregoing Principles to Trabeated or Beamed Building by the Grecian Architects.

Though the first style of construction was the most unscientific and wasteful, both of material and of space, yet did it produce the most durable buildings, and also the most grand and noble artistic effects. The durability arose partly from the great masses employed, because it required long and strong lintels to span the openings, and allow those openings to be as wide as possible; and thus a correspondent size and massiveness of stones was needed throughout. It also arose from the absence of oblique pressures, whereby every stone became independent of those above or beside it for support, so that no dilapidation of the upper parts could [as in arched buildings] endanger any thing beneath. To these reasons may be added the exact perpendicularity of

every pressure to the bed [or horizontal joint] receiving it,—an excellence that can never be *perfectly* attained in the inclined beds of arched buildings, however exact may be the calculations of the engineer; and, indeed, is never attempted. Lastly, the ambitious nations who best practised this mode of building, gave it a great excess of solidity, calculated to withstand even earthquakes, and not without success.

The unrivalled grandeur and majesty attainable by the same style of construction, when properly treated, arose partly from this same excess of solidity; partly from the bold projections rendered possible by the largeness of the stones; partly from the sublime *repose* of a structure whose pressures are *all vertical,* no side-thrusting, no action; but *chiefly* from the *rectangularity* of the openings or principal divisions, rendering possible the most perfect subordination of the other classes of form, or the omission (or reduction to any extent) of the lighter classes, and the use of the grave classes in minor details.

In the practice of this system by the Egyptains, there was perfect constructive unity, not only in the *visible*, but in the *whole* construction; all of which indeed was seen, for (the almost rainless climate rendering pent-roofs unnecessary) the only covering was a flat stone ceiling. But this absence of hidden construction was no merit (being, in fact, unnatural), and whatever other merits the Egyptian works had were counteracted by two grievous faults,—*inattention to the subordination of the five classes of forms*, and complexity, or *utter absence of unity in the general design*, even of temples, the fabrics, of all others, requiring the most of that unity.

The unity of statical design, then, in the Greek structures, was nothing new or peculiar to them. Their excellence consisted in the addition to this of the two principles above mentioned; and of these we will consider, first, the unity of general design.

The feeling which led to the use of the gravest class of form, in all principal arrangements, having decided the gene-

ral plan to be rectangular, it might at first be thought that a *square* would embody the most perfect idea of unity; and there are not wanting examples of this plan in the nave of temples without peristyles, as in the great temple of Ceres, at Eleusis, and the very small Ionic one existing in Stuart's time, on the Ilyssus, the cell of which was a perfect cube.* But when that beautiful and sublime change was made, of carrying the colonnade entirely round, making all the sides alike in character, all equally ornate, all equally impossible to appear flat and blockish, even at the distance of miles,—then the squareness of general plan was invariably given up for an oblong at least twice as long as its breadth, generally somewhat more. What was the reason for this? A square peripteral building would have led to a doubt, on approaching it, which of the two visible sides was the entrance front. Unless both were alike, the fourfold symmetry would be sacrificed; but if both were alike, both must be entrances, or appear to be so (as in the graceful work of Palladio, above mentioned). Now the appearance of only *one* entrance, and the instant discovery thereof, was evidently a most important part in that unmatched expression of unity at which the Greeks aimed, and alone, of all the nations in the world, attained. Though there were often two entrances, being placed at each end, only *one* was visible in any possible view of the building. But this was not enough; the distinct statement that there was no entrance in the side, required that (when it had a colonnade) there should be a column in its centre, consequently an *odd* number of them; while the entrance front required an opening in the centre, and therefore an *even* number of columns. Now, if the difference had been made small, (eight columns in front, and nine in flank, for instance,) the whole, if not square, would have appeared as though intended to be square; and if really square, the

* Symbolic of perfection, as we see by Scriptural texts,—Kings vi. 20; Rev. xxi 16. In all the measurements of the temple no cube occurs but that of the "most holy place."

closer placing of the columns on one side than the other, would have destroyed all the perfection and symmetry of that form ; and, in either case, the idea conveyed would be that of a blundering attempt at squareness. Abandoning this form, therefore, the architects adopted as their fundamental form the next most perfect (or regular) rectangle, viz., a *double square.*

That every temple (except that piece of barbaric pomp at Palmyra) should present its *narrower* face as the front, is referred by Papworth* to the avoiding all approach to *show*, or displaying itself to the best advantage,—a very noble idea, and one which doubtless operated both with the Greeks and their nearest followers, the Gothicists. But it may be observed, that there is a less refined reason, which has led all nations (probably, without exception,) to make the axis of symmetry in their temples *longitudinal*, and in their palaces *transverse;* the temple being always entered from its end, and the palace from its side. The latter being divided into many apartments requires the entrance in that place which will most readily communicate with them all, *i. e.* as near the centre as possible; but the temple being a single room will have the best effect when the eye on entering can embrace the largest portion of it at once, for it is impossible ever to see the whole interior even from a corner, because the eye cannot receive distinct impressions over a circle of the retina more than 45°, or at the utmost 60°, in diameter. Now by taking two lines fixed at this angle, a folding rule, for instance, and laying it on the plan of any room, you will find, by moving it about, that position in which they include the greatest portion of the area; and it will be found that the more an oblong room deviates from the square, the more of it can you thus see at once; and that, when the room is a double square, or longer, the best position for the point of view is the centre of an end; and the *worst* is the centre of

* In the excellent Essay on Grecian Architecture, prefixed to his edition of Sir W. Chambers, to which I owe much assistance in this inquiry

a side, (in which place the great temple at Palmyra is entered.) The general use of the former place, therefore, in ancient (as well as Gothic) temples, is a sacrifice of external show to internal effect.

It may here be remarked, that the nave of the Greek temples was not that gloomy, naked cell that some imagine; neither was it confined to the priests, but open to all. To Fergusson is due the merit of first elucidating how it was roofed and lighted. His theory bears internal evidence of its truth, being the most perfect mode of lighting ever employed, viz., by what we call in England a clerestory, but *without any other windows below.* There is an example of it at St. Geneviève, Paris. The Greek clerestory did not rise above, or in any way break, the simple out-planes of the roof, while it varied their otherwise too monotonous surface. The notion that most Greek temples were open courts, or (to use this writer's words) a "a sham temple," "a colonnade and dead wall surrounding nothing," is beneath notice.

But with all the precautions for external utility, it would still have been imperfect but for the *one* crowning, all-including feature—the roof, with its *one* ridge and *one* pediment (only one being possibly visible at once.) On this point, Papworth observes,—"Towards obtaining this unity of effect and character, the combining quality of the roof is obviously necessary in the Greek temple; it combines in one span the cell, the portico, and the peristyle, without which they would be viewed as parts merely, and to which the steps, or base supporting the whole, greatly contribute.

"To complete this unity of effect, only one approach was obvious under any view of the building; indeed, so carefully was this principle attended to, that on the flanks of the edifice the spaces were arranged in even numbers, so that a column was placed in the middle of its length, and not an intercolumniation, while the actual approach was always decidedly indicated by a central opening in the portico, and by the centre-marking character of the pediment."

The *base* above alluded to was always (in the pure Greek or Doric style) equal in height to about a diameter of the columns, and the architrave was the same: otherwise these two principal parts would have seemed inadequate to bear the pressure of those columns, concentrated on distinct points of their length. The base was, moreover, for convenience subdivided into *three* equal steps and no more; for, had the steps been much lower than a third of a diameter, they would have seemed thin, paper-like layers, quite out of place below those weighty masses. Neither could a Grecian eye have tolerated the breaking of these continuous lines by the introduction of smaller steps or mounting-blocks opposite the entrance or elsewhere. They preferred the inconvenience of ascending steps, 15, 20, and even 25 inches high; and unless we can submit to this inconvenience, all attempt to copy a Grecian portico will be an absurb caricature.

In all great and complete buildings, of whatever style, the basement, even to a considerable height, consists wholly of *horizontal* lines, running *without any interruption*, rise or fall, round the entire structure. Salisbury and Milan cathedrals are the grand examples, but it is seen in all smaller Gothic works if pure, and completed on one design. The peculiarity, therefore, of the Greek basement was not the unbroken *horizontality* of its lines, but their unbroken *plan*—straight from corner to corner.

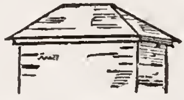
In the Grecian design, up to the roof, we find all principal members and lines horizontal, and all secondary ones vertical —a consequence of constructive truth; the vertical-pressure construction requiring all continuous joints to be horizontal, and all discontinuous ones vertical.

This truth also required the continuation of the cornice horizontally across the ends, (though not there necessary to throw off the wet,) because the two inclined cornices above would have given the expression of oblique pressure, unless tied together into one triangle by this feature. By this means the construction of the roof, though not possible to

be displayed, was *truly indicated* externally. Moreover, a support was afforded for the glorious ornaments in the pediments, which gave life to the whole.

In descending from the general design to that of the parts, we find every where (in the Doric order) the principle of *contrast* carried to the utmost extreme; the opposite one of *gradation* being as nearly as possible excluded. I am convinced that if we really understood this principle of *contrast*, and determined to embody it *alone* without compromise, in a vertical-pressure building, we should be led to the complete Doric order, though we had never seen it.

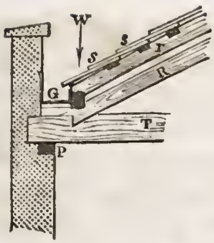
To begin with the most indispensable feature of Greek buildings, the *cornice*, (for columns and architraves were not of universal use,) we must observe that in all countries where it rains at all (even in Egypt) this feature springs out of an absolute constructive necessity: for it is impossible completely and durably to exclude wet at the junction of the roof and walls, but by making the ROOF plane advance beyond and cover this junction. (Fig. A.) It is obvious to a child that this must effect the object at once. But as in China it is necessary that women should not walk, and in Japan that teeth should be black, so it is necessary in England that this natural arrangement of roof and wall should be reversed, that the roof should be rather less than sufficient to cover the building, and the WALL raised to conceal the junction. Of course, this requires a great waste of expense in misconstruction, or rather patching, to keep out the wet from season to season; but on this, trades are said to depend; and, of course, the original falsehood has to be concealed, disguised, and palliated by lie upon lie. (Fig. B.)



A

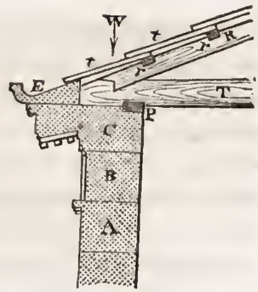
B

The tissue of errors to which we are thus led will appear more clearly by the following comparison.



Junction of the roof and wall in an English building.

P, The wall-plate. T, The tie beam.
R. A principal rafter.
r, One of the minor rafters not tied by the feet but thrusting outwards, and having to be supported by the pole-plate and a purlin (not seen) which, concentrating the whole weight *on one point* of the principal rafter R, calls for unnecessary strength therein. Above *r* is seen a *fourth* set of supports, the *first* of which four sets would have sufficed if properly distributed, since it supports all the others besides the covering.
ss, The slates or tiles made so short as by their overlapping to become much less inclined than the general plane of the roof, and thus call for unnecessary height therein.
C, The parapet or roof-hider, built chiefly on roting wood
G, The lead gutter, capable of overflowing or leaking *only within* the building, and immediately over the chief timbers.
W, The whole weight of the roof concentrated on a point far *within* the walls, deflecting the tie-beam and thereby thrusting the wall outward.



Junction of the roof and wall in a Greek building.

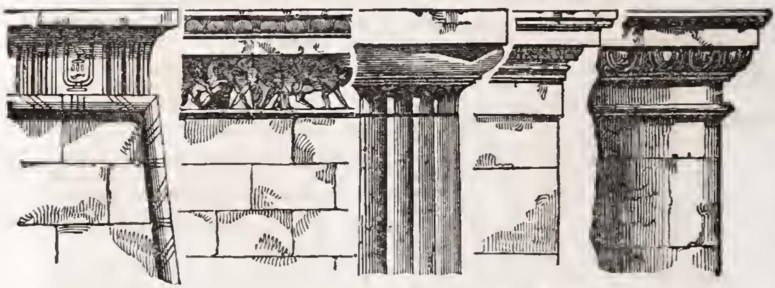
A, The architrave, or last wall-course but two.
B, The frieze.
C, The cornice or salient course.
P, The wall-plate. T, The tie-beam.
R, A principal rafter.
rr, Minor horizontal rafters or purlins, numerous enough to distribute their weight *equally* throughout the length of the principal rafter R, and immediately receiving the covering.
tt, The tiles, or marble slates, in either case made long enough to have nearly as much inclination as the rafter R.
E, The epitithedas (oversetting) or stone gutter, *entirely without* the building, and the inner brim of which, being higher than the outer, prevented the *possibility* of an overflow wetting the timbers.
W, The weight of the roof acting on the exact *centre* of the wall's thickness, *steadying* and not *thrusting* it, and not deflecting the tie-beam.

But the intense ugliness of buildings without apparent covers, or with covers just too small, and sliping down within,* of course leads to the necessity of a sham cornice,

* The *parapet* fashion is derived from the Gothic system, in which this feature was neither a deception, nor did it lead to faulty construction ; for the walls of churches thus finished were at least *two feet* thick, allowing room for a gutter in the centre, between two little walls, of which the outer constitutes the parapet, and the inner (often nearly or quite as high) receives the foot of the roofing ; *all the timbers* of which are thus raised *above* the level of the gutter and its outlets. and thus perfectly safe from wet. Dr. Moller first noticed this excellent contrivance in the minster of Freyburg ; it is the same at Winchester and other English buildings. But if we want to adopt the principles on the *thin* walls of modern shells, of course we have no means but by overhanging outwardly like the Grecian cornice

a huge construction of lath (or other pendent contrivances) and plaster, the burden of which, pulling on the thin outer screens, is supposed further beneficial to trade. This piece of scenery is sometimes continued all round, but generally confined to a side or two, and returns round the angle a few inches, in order to give the spectator the double pleasure of being deceived when so placed as to see only one side, and undeceived when he turns the corner.

THE FRIEZE OR NECKING TRACED FROM



Egyptian Wall. Greek Wall. Greek Column. Greek Antæ. Roman Column.

Below the cornice of the Greek building we always find a band called the frieze; and below the projections which crown the columns, the antæ, and every other principal member, we recognize the same peculiarity; each has its frieze or necking, the division between it and the mass below being differently marked in each case, but always by a line of shadow. In the *general* necking of the building (at least of a temple) this line of shadow is cast by the projecting fillet called the *tania;* in *antæ*, and the basements of some tombs, it arises from a general *overhanging* of the frieze before the plane below ; and in *columns*, and the basement of Lysicrates' monument, it is formed by a *groove*, the direct reverse of the first method, but agreeing with it in the production of a line of shadow. This peculiar *echo* of the main shadow, by a smaller one beneath it, seems to have been first faintly developed in Egypt, seized upon and (like every thing they

touched) perfected by the Greeks, and to have descended by tradition for 3000 years, through all the vicissitudes of Roman, Romanesque, Gothic, and post-Gothic fashions to our own day.

A hundred generations of men have now admired this peculiarity,—have felt that it could not be omitted without deterioration of beauty. Why is this?

Let us hazard a conjecture. We have said that there can

EGYPTIAN INTO MODERN ARCHITECTURE.

Roman Arch-pier. Early Gothic Shaft. Gothic Basement. Late Gothic Pedestal. Modern Wall.

be no contrast between two things totally dissimilar. Consequently, there can be none between two such things as a cornice or capital, and the wall or mass below it. They have no point in common. Now, if we can introduce between the two, something that shall have a resemblance to the cornice in one respect, and a semblance to the wall or mass below in another respect, it may form a contrast with each. This can be done by cutting off (by a line,) from the general mass, a portion about equal in height to the capping, or the mass of shadow cast by it. This will resemble the dark band above in *size*, but contrast with it in *luminosity:* it will resemble the mass beneath in *position* and *luminosity*, but contrast with it in *size;* and thereby increase its apparent height, which, I think, any one must perceive a frieze or necking to do.

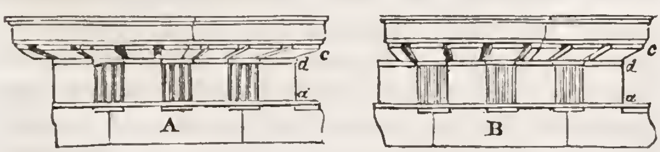
In Egypt, the frieze and cornice formed one concave

sweep, [though the intense sunshine of that climate casts the shadow of the latter in such a way as to form a sharp contrast of a dark and light band nearly equal.] But the Greeks, aiming at the most unmitigated contrast, thought the curved surface too light a form for the severe sublimity, which was their object. They, therefore, made the *soffite* and the *frieze* two distinct planes, meeting [at first, probably,] with a right-angled nook. The *mutules*, fancied by some into copies of wooden construction, have not the slightest resemblance to any thing of the kind, being far too thin and broad for any rafters' feet; moreover, the practice of falsification, or copying one material in another, was totally opposed in principle to every thing the Greeks ever did. These features, together with their *drops*, are supposed, by Papworth, to be intended among other purposes to break up and confuse the edge of the shadow cast down on the frieze, which edge, if straight, would most harshly cut the sculptures thereon by a sharp line, besides appearing like an architectural division, which, varying in place with the time of day, could not always be pleasing; and "that principle in architecture would be violated which prevents the projected shadows from disturbing the adjusted proportions." The triple tiers of drops, it may be observed, so situated as to be *always* seen in perspective, present the only ornament consistent with severe simplicity; owing all its beauty to regular repetition of similar objects, without any beauty of form in the objects themselves, or any introduction of the principle of *gradation*, except that unavoidably produced by perspective. The idea of such an ornament may have been taken from plants in a field, uniformly arranged for agricultural economy.

The triglyphs are now generally thought to have been [as regards the mere idea] derived from the clusters of upright reeds alternating with ciphers or monograms on the Egyptian frieze-cornice. But it seems to me that the mere aim at contrast and severe simplicity is quite sufficient to have

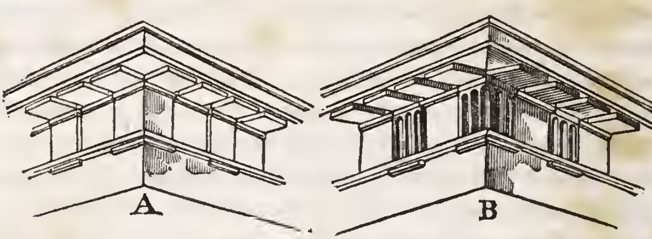
rendered them necessary. The mass of horizontal lines in the entablature required to be contrasted by vertical ones, and the frieze was the only place admitting them, the cutting of the *architrave* vertically being such an obvious faslehood as not to be entertained for a moment, while the chief plane of the *cornice* was horizontal. But the vertical lines could not be repeated all along the frieze without, not only great monotony, but positive physical injury to the eye, as any one may find who looks intently at a numerous set of parallel lines. The alternation of a group of liues and a square of sculpture more completely carried out the principle of contrast, besides giving a field for the sculptor. In Egypt, each of these groups of vertical lines consisted of five or six hemi-cylinders ; but the Greeks confined it to the smallest number of repetitions that could exhibit equal-spacing, viz., *three*,—and, instead of the soft rounded hemi-cylinders, they adopted the graver form of *octagonal prisms ;* obliquity [but not curvature] being admitted in these minor features, rather to enhance the severe rectangularity of principal parts, than from a childish search after variety.

The two planes of the frieze and the soffite being thus each crossed by transverse lines, it became an object that these two systems of lines should make the most *intensely* rectangular contrast with each other, not really—but *visually :* for this purpose, the real angle between them was diminished to less than a right angle, by making the soffite slope forward, which has the effect intended in whatever way viewed, as will be seen by the following sketches.



A represents a Doric entablature, with the soffite sloping over in the usual manner, in which it will be seen that all

the angles *a*, *d*, *c*, &c., appear, in consequence of the perspective, more nearly right angles, *i. e.*, more abruptly *contrasted* than the corresponding angles in Fig. B, which shows the appearance of a horizontal soffite. This effect will be equally true in an angular view, as seen in the two figures below. (A horizontal,—B inclined soffite.



We must here, again, protest against that insolent libel on the Greek architects, the *wooden* theory of Vitruvius and Milizia, who, of all writers on architecture or building, perhaps give the fewest hints at general principles. In the case of the inclination of the soffite, this barbarous theory is at once disproved by two facts, the inclination being observed on the *fronts* equally with the sides of the building, and its angle being wholly independent of that of the *roof*. To aid the effect, the frieze was made to incline imperceptibly backward, and the architrave also, because any want of parallelism between them would have become obvious at the corners.

The architrave being evidently the most important constructive member in this style, we need not comment on the perfect fitness of the severe, uncompromising plainness, strength-expressing squareness, and majestic breadth of light and shade, on its face and soffite. The only approach to decoration* appears at its very top, and so connected with that of the frieze, as evidently to be intended only to reconcile the abrupt difference (not contrast, but *contradiction*)

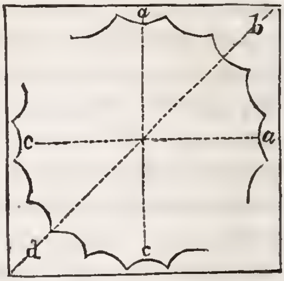
* The shields and other metallic objects *attached* to the architrave of the Parthenon, being not *a part of it*, did not interfere with its nobly severe expression.

otherwise occurring between the completely ornate and completely plain member. The decoration is applied under each triglyph, because the same number and quantity of horizontal lines that suffice to support and bound the metope sculpture would not suffice to *stop* and contrast these groups of strong vertical lines. The principle is exactly that which led the Italians, whenever they had a string-course serving as sill to a tier of windows, always to attach *something*, it hardly matters what, under each window or each window-jamb. The sub-triglyphs are simply repetitions (with less projection) of the mutules; and this repetition serves more than anything else, except the *cap and necking* repetition, to give unity of style.

Descending to the column, we must observe that the profile obtained, as already explained by the generalized imitation of limbs, though perfectly proper for the support of a plane extending in *every* direction from the capital, (as a flat ceiling,) requires an addition to fit it for placing under a beam that extends on only *two* sides of it. Unless the architrave were as wide as the *echinus* (which would render the whole top-heavy), it would not press on the *whole* of that member which is essential to preserve the analogy with an animal extremity. The *abacus*, then, presents the simplest possible way of spreading this pressure over the whole capital, and its thickness is regulated by what is found by experience just to give the expression of sufficiency to this purpose. If too thin, it is apparently useless, and if too thick, unnecessarily massive.

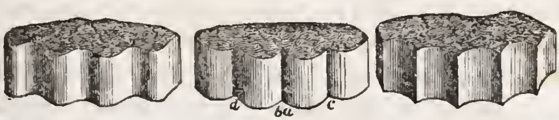
The shaft, as already noticed, though required by convenience to be *round*, is, nevertheless, made to present *square* (right-angled) edges. Nothing could be so contradictory in principle, to everything else in the Doric order, as the sleek *fatness* of a completely rounded shaft, whose mass only gives it clumsiness without the slightest expression of power. A Dorian entirely debarred from the use of flutings would have made his columns square, at whatever sacrifice of con-

venience. The first improvement on the square would be by truncating its angles, to reduce it first to an octangular, and then to a 16-sided prism. But the contrast between two successive sides of this being very slight, and liable to be counteracted by the faintest weather-stain, this contrast was exaggerated to the utmost, by so hollowing out each face as to reduce the arris to a right angle. The same thing was done for the same reason by the Gothicists in many of their octagonal features (see ninth example in the parallel of neckings in p. 185). There is only one case, however, of the 16-sided shaft—that bold example crowning the promontory of Sunium (Cape Colonna), evidently designed for distant view. Everywhere else we find the sides increased to twenty, on account of the common-sense principle which requires that in every structure, as solids should be over solids, and voids over voids, so should projections be over projections, and recesses over recesses. Let the square in the annexed figure be the plan of the abacus, and *a b a*, part of that of a 16-fluted shaft. If a recess be placed as at *a a*, beneath the most receding parts of the abacus, (or those nearest the axis,) then a recess also, as at *b*, will come under its most prominent point. But by increasing the flutes to twenty, one can be placed centrally under each face of the abacus, as at *c c*, and an arris (or greatest projection) at *d*, under the angle of that member. This could not have been obtained with any other number of flutes, between twelve and twenty-eight, of which the former might probably be used with advantage in bold plain engineering works, but the latter would introduce too much of the principle of gradation, in the *seven* gradually diminishing quantities, from the visual middle of the column to its visual side.



It might be thought that contrast would be better consulted by making every recess or flute, a pair of planes meeting in a nook, as if the plan consisted of five superposed squares (as practised in some Egyptian works with a smaller number) ; but not only would this introduce unnecessary complexity by doubling the number of lines, but by drawing the outline elevation of such a column, we shall find, in going from the centre to the side, a breach of continuity—a sudden change in the law of gradation, at that recess where we first lose sight of the nook-line. Though gradation was to be avoided, it was felt that wherever it did unavoidably occur, it should be continuous. A sudden breach in *any* gradation is ugliness, because it is neither regularity nor irregularity. It is the same principle on which we condemn the sudden change of curvature in the Tudor arch, and any change from one curve into another, except the perfectly contrasted flexure, as noticed in Chapter II.

There are obviously only three *simple* modes of striating columns—by convexities alone (*reeding*)—by concavities alone (*Doric fluting*), and by alternate concavities and convexities (*scalloping*). The last is the mode most common in



Scalloping. Reeding. Doric fluting.

nature, because regular striation is here confined to *elegant* (not *grand*) objects, and this is abstractedly the most elegant kind, being all gradation and no contrast. Of the other two modes, the Doric affords most contrast, for several reasons. First, all its lines (which are the only places where contrast of light and shade can occur) are visible,—while in the reeded column, only a few of the nook-lines can be seen at once. Next, only two of these nooks in the reeded example can so receive the sun as to have one side shaded and yet the other not shadowed by it as at *a*, *b*. In the nook *c*, both

sides receive light, though not equally; and in *d*, one casts its shadow on the other: now the edge of a cast shadow can never have the sharpness of contrast that an actual edge of a body has. Moreover, in concave surfaces, as already remarked, the cast shadow of the edge often (in sunshine) reduces great part of the concavity to equable shade, and thus obviates part of the gradation that is unavoidable on convexities.

The angular plan of the column ceases at the top of the shaft, because its continuation throughout the swell, or echinus, would introduce too many curved lines. It would be more elegant than the present capital, but less fit in a composition of which grand severity (not elegance) was the aim, and in which the curves were made as few as would just suffice to give greater value to the general rectangularity. The long fluting lines, then, being stopped suddenly, the same principle that called for the sub-triglyph, required here the contrast of strong and repeated horizontal lines. *One* was not sufficient to stop such long and strong lines as the arrises; so *three*, *four*, or *five* of these stopping lines (*annulets*) were made, according to the height of the column, and their profile carefully studied to produce the strongest alternation of light and shade. The Pæstans trusted to intensity instead of number, and substituted *one* deep, black hollow, but the leaves introduced therein show a great decline from Doric severity. Indeed, all the colonial examples are very impure.

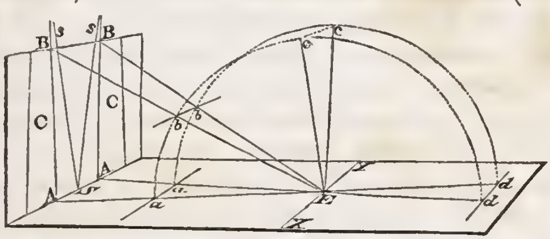
The *diminution* and *entasis*, essential to the character of limb-columns, do not, as might be thought, interfere with the severe rectangularity of the style, but actually increase it when seen from a near point of view. To explain this, we must remember that the ocular images of objects are formed on the retina, which is not a plane but a *spherical* surface, and the most severely contrasted angle is not always an actual right angle, nor yet that which appears most so in perspective, but that whose image on the retina is most right-angled. Every designer should understand *spherical perspec-*

THE ARCH OF HADRIAN.

page 271

tive, i. e., projection on a spherical surface of which the eye is the centre. It is by no means a difficult subject, perhaps easier than ordinary perspective ; and the architect would do well to consider (as the Greeks did) not only the elevation, and the effects in plane perspective, but especially the spherical projections of any thing, for those alone are really its *visual* appearances.

Now, when we examine a colonnade, arcade, or any similar alternation of masses and voids, we never place ourselves opposite a mass or projection, (column, pier, or buttress,) but always opposite a recess, (intercolumn, arch, or window. The visual outline of the column, then, is less important than that of the intercolumn. Every one must have observed, when opposite a Doric intercolumn, at a distance about equal to its height, or rather more, the *intense squareness* of its effect. This is because its ocular image is *more* rectangular than if the opening were actually rectangular, like a doorway. Let E, in the following figure, be the place of the eye in a horizontal plane, X X ; and let the vertical plane A. C, A C, contain the geometrical *elevations* of two columns, C C. If the sides of the intercolumn (or A. B,



A B) were vertical, they would be projected in spherical perspective as two portions of *great circles** meeting in the spectator's zenith. Consequently, the image of the opening would diminish upward, like a piece of one of the gores of a globe ; and its top, B B., being projected, also, as a portion of a great circle, would make an *obtuse* angle with each of the sides. But let it be required to make the ocular image

* Every straight line becomes in this projection a portion of a great circle

as seen from E, parallel-sided and rectangular. The sides of this image will then be parts of the two parallel circles, *a b c d*, *a b c d*. The rays drawn from E through every point of these two circles will form two very obtuse cones, whose common vertex is at E, and their common axis X X ; and the vertical plane C C (being parallel with their axis) will so cut these two cones as to form the two hyperbolas A B, A B, which will be the form that must be given to the lines that are to *appear* parallel, as seen from E. To give the opening, therefore, the utmost effect of rectangularity, (as seen from this distance,) the sides of the columns must be a pair of opposite hyperbolas, having their common centre at S, and their asymptotes, S, *s*, S *s*, making the same angle as E *c*, E *c*, consequently the same as A E A ; or the angle which the breadth of the intercolumn subtends from the distance chosen, which distance will vary greatly of course in different designs, but can never be less than the height of the order, because the eye cannot see the whole of an object at once that subtends more than 45°.

Whether this were the exact curve given to the entasis, I have no means of ascertaining ; but this seems the only reason that will assign any particular curve. With regard to its dependence on a certain chosen distance of sight, it must be observed that, nearer than this, we can only see details, and hardly take in a whole column or intercolumn ; while, at all greater distances, we take in *several* such divisions, and estimate their form rather by the *axes* than the *outlines* of the columns, so that their limb-like form does not interfere with the rectangular nature of the principal divisions.* The thought and provision bestowed by the

* Few things in modern Grecian caricatures are uglier than the upward expansion in the width of a colonnade of some length, as the longest one in the front of the British Museum. The columns being set with their axes upright, their inner sides lean away from the wall, and (when viewed from one end of the avenue) appear falling. This effect cannot happen with a *short* portico, whose length does not much exceed its height, because the opening at the further end, (like those mentioned above,) though not rectangular, will appear so. But the further it is removed, the less correction of this kind will it receive, so that the longer the colon-

Doric architects on the effect at *every* possible distance (from miles down to inches, from their work) is most remarkable.

The *optical corrections* are another most admirable refinement peculiar to the architecture of the Greeks. This effect does not require the presence of more than one column, (so that it cannot depend on the intercolumn,) and it disappears beyond a moderate distance. It is explained perfectly by the fact that when the eye is directed to the middle of the column's height, (which it must be to see the whole,) the upper and lower parts being, the one more distant, and the other nearer, than the part to which the eye has adjusted itself; they will both produce on the retina, indistinct images, out of focus, and therefore too wide. The effect may be perfectly imitated with a model of the eye, or a camera-obscura. But the entasis in Greek columns is commonly *more* than sufficient to correct this illusion, and so we should expect both from the treatment of the intercolumn above explained, and from the generalized imitation of natural columns.

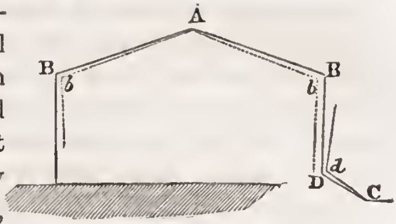
But the most general source of the illusions to which these corrections were applied, was *irradiation*, or the spreading of luminous impressions on the retina. It is this which makes the angular column of a portico, seen against the sky, appear narrower (unless made broader) than the others seen against a ground darker than themselves. In each case, the lighter image encroaches on the limits of the darker, —the sky on the dark column,—the light columns on their back-ground. As this fact (perfectly established in optics) is strangely disputed by some architects, we subjoin a figure that will furnish an experimental illustration. Let the reader, from the distance of

nade, the more should the axes of the columns lean inward, though they never need lean so much as to make the inner sides quite vertical. We should therefore observe this proportion. The width of the passage at the floor : that at the ceiling, : : its length : the diagonal formed by that length, and the height from the eye to the ceiling. This rule would make the inward inclination of the columns on the *flank*, of a temple, greater than on the *front;* which the latest measurements, I believe, have shown to be the case

a yard, estimate the relative widths of the two ends of this rectangle, and then measure them. The drops under the tænia, if made cylindrical, will appear to taper downwards, from their tops being seen against the shadow of the fillet above, and their lower ends against the bright surface. To correct this, they are made slightly conical in the contrary direction. So, also, columns with vertical sides seen against a wall, the upper parts of which are shaded more than the lower, (as always happens behind a colonnade,) will appear to taper downwards; and to correct this, seems the only object in the slight and hardly perceptible upward diminution given to antæ, and perhaps that of columns in the lighter orders, which are not imitated from the animal type.

Some other corrections may be called rather *æsthetic* than *optical*, being directed against illusions of *perception* rather than sense; many of which may be traced to the well-known effect of *contrast*, always to make the difference between the things contrasted appear greater than it really is. Red and green placed together, appear redder and greener towards their junction than at a distance therefrom; and this I hold to be applicable to all contrasts of whatever kind.* Thus, *angles* being contrasts, the difference of direction between their two lines will seem greater than it really is; and hence, except in the case of a right angle, (where this difference is a maximum,) it will be increased; *i. e.*, every oblique angle must appear less oblique than it is; an acute angle be apparently increased, and an obtuse angle diminished. To this I attribute the fact, that the general outline of a portico, with all the axes of its columns vertical, seems *broader at the top*,—an effect not, I believe, observable when there is no pediment. In the outline, we have three obtuse angles, A B B, each of which being apparently diminished, (as by the dotted lines at *b b*,) all will evidently conspire to make the

* It is very obvious in contrasted *dimensions*. Whenever they are not greatly different, (those of the faciæ of an architrave, for instance.) we shall on measurement always find that we have *over*-estimated the difference



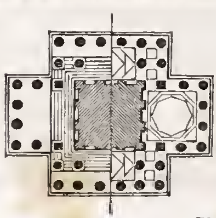
sides apppear to overhang, and the effect will be further increased when the outline is connected with the ground-line, not by a right angle but by two obtuse ones, as at D C, (which often occurs from a flight of thin modern steps, or from perspective lines of stylobates, &c.) The mere diminution of the corner column is not sufficient to counteract this effect, at least not in the case of the lighter orders, where the diminution is so much less than in the Doric ; and hence the axis of the column should be inclined, and, to equalize the spaces between the capitals, of course the axes of all the columns must have a general upward convergence. This agrees with the result of the latest admeasurements.

The antique orders seem to have originated in different parts of the world—the Doric being the only one that can properly be considered a Greek invention ; the Tuscan a modification of the Doric ; the Ionic an Asiatic importation. The Corinthian a refinement on the Egyptian and the composite rather what its name would import than a separate order. In all Asiatic styles, also, there is a tendency towards lateral projections from two opposite sides of the capital, sometimes turning upward, and serving as brackets to the architrave ; sometimes pendent, and reminding one of volutes, though not taking that form. The *base* is another Asiatic feature, and regularly increases, the further east we go, till in India it sometimes, with its innumerable moulded details, reaches to a height exceeding that of the shaft itself.

Before its adoption in Greece, the Ionic order was carried to considerable perfection in Asia Minor, in a form more nearly approaching that now used, but greatly inferior to the Athenian improvement, which we have already briefly mentioned as arising from an accurate feeling for the subordination of the five classes of form which in the Asiatic examples were much misplaced.

There is a fair specimen of these works in the fine tomb or monument whose remains fill the Lycian Room at the British Museum, and I think any one must be shocked at its want of an apparent architrave, and at the huge block-like dentils, fit only for an engineering work, placed above so delicate an order. *These* features are known to have been anciently practised in Asia Minor, but never in Greece.*

* These remarks must not be misunderstood to apply to any thing beyond the *order;* the general form and arrangement of that and other Ionion tombs being above criticism, for their grace, lightness, variety, and cheerfulnees, so opposite to the gloomy ugliness and sham massiveness, by Christians thought essential to every thing sepulchral. The most famous of these monuments, that of Mausolus, which has given a name to all pompous works of the kind, has unfortunately left no vestige ; and the statement by Pliny, that it measured on the north and south 63 feet, but was shorter on the *fronts*, yet 411 feet in entire circuit, has made it a kind of problem to restorers. Supposing the *fronts* to be (as in all ancient buildings) east and west, it will be seen that the plan mnst have been either *eight-sided* or *cruciform.* The former would by its oblique angles exclude the use of the Ionic (the national and sepulchral) order. The expressions "attolitur in altitudinem XXV cubitis : cingitur columnis XXXVI * * supra pteron pyramis altitudine inferiorem (pyramidem) æquavit, XXIV gradibus in metæ cacumen se contrahens" seem to imply a basement 25 cubits high, then a colonnade, and above it a pyramid, equaling the height *of that below* (surrounded by the colonnade.) The finial was a quadriga, making the total height 140 feet, whence that of the basement and quadriga being deducted, would leave 80 or 90 for the order and pyramid or about 40 for the order alone, whose columns, if Ionic, would be about 4 feet in diameter. The annexed arrangement shows how 36 of them, with a systyle spacing, could serve to cover the whole plan, by means of *trabeated domes*, (like that of the beautiful tomb at Mylassa,) resting outwardly on the columns, and inwardly on the sides of the pyramid. A hexastyle portico, 63 feet wide, would appear on each flank, and a tetrastyle one (with a pediment) on each front ; and no beam would be required of greater span than 11 feet, that of the architraves being only 8 feet. A late restoration which challenges the "production of a better" has nearly all its architraves of 17 feet span, and forming the *only base* to a pyramid extending over the whole plan, (which has about double the area of that here given,) the most massive of all architectural forms being thus *hoisted in the air* on columns, and these of the Corinthian order!



Plan looking down. Plan looking up

The immense temple of Ephesus, and others, hardly inferior, in most of the cities of that country, were Ionic; but the European Greeks, with their general accuracy of taste, confined this order to their smallest works, in which, sublimity being unattainable, elegance was substituted; and perceiving that the character of their national style would be entirely lost, without any equivalent, when the columns were reduced in thickness to less than a sixth of their height, (the proportion of a lion's leg,) they wisely rejected it in such buildings.

Of the exquisite curvilinear forms invented for the adornment of the Ionic order, none is more general, and yet less understood, than that called by them *anthemion*, and by us, the honeysuckle, though it has not the slightest resemblance to that plant or any other, being no representation of any thing in nature, but simply the necessary result of the complete and systematic attempt to combine unity and variety by the principle of *gradation*. First, a "line of beauty" was formed,—a line of contrary flexure, of our fifth class,—not of *contrasted* but *gradated* contrary flexure. On the principles explained in Chap. II., the unity and variety were further augmented by a gradated increase of breadth from one end of this line to the other; then a series of such lines were combined, not all alike, but gradated from the longest to the shortest. But as this did not produce a symmetrical or uniform figure, the uniformity of halves was obtained by joining two such series of lines in reversed positions: thus we have one of the tuft-like forms that compose the pattern. At first these tufts would be made all alike, but they would soon discover the graceful variety attained by using two such forms alternately, differing chiefly in their *number* of lines, but both composed in the above manner. As the lines, however, composing these figures are not long enough to afford an *extensive* display of gradated curvature, such as gives to spirals their exquisite grace, the artists could not forego the introduction of longer lines, in which the curva-

ture (evanescent at their middle) increases up to each extremity so as to form curls or volutes ; and these, associated with the above forms, complete the *anthemion* in all its varieties.*

Ionic anthemion.

Doric fret.

As a systematic attempt to embody as perfectly as possible, in a beamed building, the one principle of *contrast*, would lead any designers to the Doric order and nothing else ; so the attempt, in an ornament, to embody *gradation* alone and unmixed, must lead to this precise combination of forms. The tracing of the solutions is easy after the problems have been solved. We can all make the egg stand, after Columbus.

The introduction of the anthemion into the Doric order was, in itself, a great abuse, but was palliated by certain changes made to diminish gradation and increase contrast, such as the omission of contrary flexure in the curves, *(i. e.,* reducing them from the fifth class to the third,) the terminating them by angular instead of rounded ends, and the enclosing of each set of curves in the Gothic-arch-shaped border, crossing and violently contrasting with their direction. An ornament more fit for this order (but perhaps carrying the rectangular principle to excess) was that called the *fret*, which, it should be observed, was, anciently, never more than a *painted* form. It was left for the age and country of Soane to perpetuate such a thing in carved marble.†

* Since arriving at this conclusion, I find Hay, in his "Essay on Form," has explained this ornament on similar principles, and rejected the notion that it is imitative.

† We must here warn the reader against a remarkable error of Ruskin. The value of ornaments in architecture depends *not in the slightest degree* on the *manual labor* they contain. If it did, the finest ornaments ever executed would be the stone chains that hang before certain Indian rock-temples. But the value of ornaments depends wholly on the amount of thought, of *mental labor*, embodied ; and whether this be great or small, it is essential that it be *not exceeded*

What Sir J. Reynolds observes of his art, is applicable to every other.—"Such as suppose that the great style might happily be blended with the ornamental,—that the simple, grave, and majestic dignity of Raffaelle, could unite with the glow and bustle of a Paolo or a Tintoret,—are totally mistaken. The principles by which each is attained, are so contrary to each other, that they seem in my opinion incompatible, and as impossible to exist together, as that in the mind, the most sublime ideas and the lowest sensuality should at the same time be united."—*(Discourse* IV.*)* And he also remarks, "Some excellences bear to be united, and are improved by union; others are of a discordant nature, and the attempt to join them only produces a harsh jarring of incongruous principles. The attempt to unite contrary excellences (of form for instance) in a single figure, can never escape degenerating into the monstrous, but by sinking into the insipid; by taking away its marked character, and weakening its expression."—(*Disc.* v.) Such was the attempt to produce a *Doric ornament* (a contradiction in terms); and the result, the rectangular fret, may well be considered (with all its varieties) the most monotonous and insipid thing ever used *as an ornament* by the ancients.

If we extend the term "ornament" to the glorious sculptures that formed a necessary part of the Doric order, that filled its cell-frieze (in low relief,) its metopes, (in higher,) and its pediments, (in detached statuary,) then we may well consider it by far the most ornate (or rather richest) order or style ever executed. The invention of a fit substitute for these, *i. e.*, one that shall produce the same *architectural*

---

by the manual labor, for then the latter will appear thrown away. The Doric fret contains thought, but not enough to render it worth carving, perhaps hardly worth careful painting. But the Doric column and entablature contain such unexplored volumes of thought, that *no* material or finish is too fine for them. Though executed in polished porphyry, the head-work would outshine the handiwork.

It is far better that the thought be inadequately expressed, that the workmanship be not worthy of it, (as in foliage of edgeless cast iron, for instance,) than that the design be unworthy of the manual labor, as in Soane's carved frets.

effect, and harmonize with the rest of the composition, is the main problem to be solved in the adaptation of this grand style to those few modern purposes in which it may and ought to be employed.*

The Corinthian order, with all its elegance, indicates the approach, if not the commencement, of decline in Grecian art : if not in architecture, at least in *sculpture*, of which this order did not absolutely *require* any. *Carving* had usurped its place, doubtlessly because the sculptors were no longer capable of executing those wonders, by the side of which all later sculpture would have seemed barbarous.

In the decline of taste, in all countries and in all arts alike, every thing is ornament, if not fritter, and no beauty is seen in the pure noble breadth and simplicity of the earlier productions. The Parthenon itself could not spurn from its eternal surfaces the brush that found them a convenient field for the display of its ephemeral fancies. First, the few mouldings were covered with forms imitative of the cut mouldings of the delicate orders ; from narrower surfaces,

* Convinced that Greek architecture (being founded on nature and truth) can *never* lose its influence, never cease to be used (be it ever so useless,) nor cease to be practised (be it ever so impracticable,) we must find it a matter of some importance *how* it shall be imitated, whether used or abused, applied or misapplied. A few words on the more obvious and gross failures of our imitation. may not be here misplaced ; especially regarding the substitute necessary for the Doric metopes and pediment-sculpture. In interiors and on northern fronts, I can see no objection to painting or inlaying. in the style of the ancient vases, the figures lighter than the ground, and varied by lines or drapery-folds, but with no attempt at deceptive shadowing. In fronts receiving the sun, however, this will not answer ; great relief and *roughness* are there requisite to break up the otherwise straight shadow of the cornice. Where the figures are not phonetic, but mere patterns, it will be needful for severity of expression that they be of the second class, *i. e* , chiefly composed of straight lines, but diagonal ones (in the metopes, to avoid confusion with the surrounding lines, and in the pediment, to avoid a graver style of form than that of the member itself.) Iron gratings, of large and simple, but carefully studied and varied patterns, might be placed before a dark tympanum and metopes (the latter much more recessed than anciently, as every recess should b , to suit this climate) ; and to procure those masses of light in pleasing forms, necessary for the due effect at a distance, polygonal or star-like portions of these gratings [one in each metope and three or five in the pediment] might be filled up, not with a flat surface, but with several planes forming a pyramidal or gem-like variety of surface, giving business and play of light and shade, without deviating from rectilinear form

they advanced to broader, till even the abacus was made a pattern-block. When the noble Dorian works began to be thus desecrated is uncertain, but probably not till a late date, as no Greek or even Roman writer makes the slightest allusion to the practice. On the contrary, the constant use of the term *white stone* (or marble) in their descriptions of buildings shows that a value was placed on that whiteness, which alone could render (even under a Grecian sun) some of the delicate adjustments of light and shade visible. The low relief of the cell-frieze of the Parthenon, perhaps rendered a colored ground necessary, even to understand it, in its dark situation, just under the ceiling of the colonnade; and probably the metopes and pediment sculptures, though not requiring such a contrivance for relief, had it at an early date; *not originally*, or the tympanum would have been built of a deep-colored stone (as that from Eleusis, used for relieving the metal sculpture of Ionic friezes,) for the taste of that day avoided paint wherever variety of color could be given by different materials.

If there were any coloring on the Doric temples in times of Doric taste, it must have been confined to a few members, and intended to enhance the general monotony, just as a few cases of curvature and variety in form enhanced the general rectangularity. That monotony of color is essential to the grand style, we may learn from all the works of nature in this style;—grand animals; grand vegetables; rocks; but especially mountains; for in these, if covered with vegetation, there is a sort of utilitarian necessity for variety of color; and yet as soon as we retire to the distance requisite to see the whole, or a portion large enough to be grand, the atmosphere interposes its blue veil, and reduces the whole to sameness. What can more distinctly show that Nature *will not suffer* polychromy in her Doric works?*

* What the air does here, *time* often does for works of architecture. In a great and ancient building whose polychromic decorations have been sobered down by ages of neglect, till hardly distinguishable, a singular majesty is acquired from *this* circumstance, and not from the polychromy itself. Not only the venerable age,

It is possible that some of these temples, when composed of a coarse material, might have had the whole surfaces finished with some kind of stucco, paint, or varnish ; and if the profiles were so adjusted as to give forcible shadows, and no nicety requiring whiteness for its exhibition, a deep, intense, and uncommon color (red, for instance,) might perhaps harmonize with the severity of form better than whiteness.

As for the painted *ornaments* on the Parthenon, if they had been contemplated in the design, they would certainly have been carved, or (if flatness were wanted) inlaid, and not executed in so mean a manner, by those who rejected marble and chose ivory, for the statue within, because *though less beautiful and durable, it was more costly.*

It should be remarked, that the unparalleled excellence of the *sculptures* of this building has led to the habit of considering it the perfection of Doric *architecture* also, which is by no means so certain. Being built after the introduction of the Ionic, and nearly contemporary with its neighbor the Erechtheum, the richest example of that order, it certainly displays many approaches to Ionicism. The older examples have, besides their simplicity, decidedly more grace, particularly in the capital ; nor can any compete in this respect with that most archaic form, of unknown antiquity, which crowns the rock of Corinth, with its columns of a single stone, only four diameters high, and yet (what wondrous art !) not only not clumsy, but singularly graceful. The loss of their entablature is one of the greatest losses architecture has to mourn.

As the Homeric poems have triumphantly refuted the attempts to regard them as compilations, so is there in the Doric order, and especially in its oldest examples, that per-

---

but the *dimensions*, are apparently increased by the dim and misty effect that makes everything look more distant than it is. Cicognara and Zanotto attribute to this cause great part of the sublimity of the interior of St. Mark's at Venice ; "an effect," says the former, "*most rare* to be obtained in edifices overloaded with so many rich ornaments "

fect consistency and unity of idea that proclaims it to be, in all essential points, the production of one mind. Like other orders and styles, it must doubtless have received improvements from many hands; but unlike them, or rather in a far greater degree than any of them, does it exhibit the marked predominance of one genius; and on this point we are constrained to receive the tradition of Vitruvius, that whatever number may have aided in its progress, it had *one inventor*, the greatest mind that has ever been directed to architecture.

CHAPTER VI.

Application of the same Principles to Compressile Building, by the Mediæval Architects.

The Greek architecture, having in itself few elements of change or corruption, survived in tolerable purity for a longer period than any other known system, and even in its latest works (few of which, however, were durable enough to remain to us) it escaped one fault, that seems to have had a great share in breaking up all other styles, (the Egyptian, Roman, Hindoo, Arabian, and Gothic, for instance,) viz., the use, as ornaments, of miniature models of the principal features;—the puerility that led, in Egypt, to making a capital like a little house or temple; at Rome and Baalbec, to enclosing a niche with small columns and a pediment; in Gothic England, to applying *buttressets* and *pinnaclets* without number; in India, to a similar crowd of modeled colonnades, verandahs, and domes; and in Moslem lands, to shelves and cupboards like cloisters, and to that multiplication of little sham vaultings that has obtained the name of the *stalactite ceiling*;—the object of all being to get false magnitude by diminishing the scale; an artifice that never succeeds except *on paper*, on which these things often look vast and sublime, but never in reality. The Greek system escaped all this; but one change, the introduction of oblique pressure, destroyed it.

The Romans (as the reader should be aware) succeeded in imitating no order but the Corinthian, and this only when they adhered strictly (at least externally) to Greek *construction* as well as decoration, as in the Pantheon portico, the temples of Nismes and Baalbec. The columns and entablatures stuck on the face of an arcade, as in the Colosseum, are a constructive lie, but not, as some suppose, a huge ornament. The lie consists in their *appearing* a mere ornament, while they are really indispensable to stability; for these columns are really the *buttresses* or props of the internal vaulted ceiling, and they would have to stand out obliquely and form apparent props, were it not for their entablature, which (often itself a piece of disguised arch construction, in order to throw all its weight on the columns,) serves the purpose of the Gothic pinnacle, to steady the column below, against the side-thrust; by combining its vertical pressure with the oblique thrust, to produce a resultant more nearly vertical, and capable of being confined within the foot of a vertically placed column.* But the column is false, because it appears made to sustain the vertical pressure alone. Being a prop, it should have appeared one; but this was never attempted till the thirteenth century. Till then, propping, though a sound principle in building, was considered an improper one to appear in architecture; and this *one disguise* kept the art for fifteen centuries in a continually deepening degradation.† The *arch* was introduced by the Etruscans or Romans; but its necessary attendant, the *prop*, was strugged against for fifteen centuries before architects would admit it without a mask.

During this long period of false art, *mixed construction* was

* Thus, these attached columns and entablatures are (as Pugin expresses a principle of all true architecture) *not constructed decoration, but decorated construction.* He regards it as a peculiarly *Gothic* principle, which is a mistake; it is not more a principle in good Gothic than in *all* good architecture, and was, perhaps, on the whole, (taking all the works of a style together,) *less* attended to in the Gothic than in any other style, before the introduction of sham building.

† What, then, can be expected at present, when *all* architecture is disguise, concealment, and deception?

universally employed (as at present); the three principles of the beam, arch, and truss, being indiscriminately used,—the first, in both stone and wood coverings of small span,—the second, in the generality of stone coverings,—and the last in those of timber, of which only the roofs or ceilings were (at least after the last great Roman works, in the reigns of Constantine and Diocletian) entirely composed. One consequence of this was, that the long dark age of architecture produced no durable works; so that we hardly have any examples (or not enough to show us the general manner) of more than its *first* two or three, and *last* two or three centuries. The style of the former is called Roman; of the latter, *Romanesque*, or (in England) Saxon and Norman, and by various local names in other countries. The durability of the Roman works arose from the national energy of character, and from Greek principles of construction being retained in porticoes, &c. The durability of the Romanesque arose from a general return to more substantial construction after the year 1000, which was expected to terminate the world; and also from the desire (caused by the frequent destruction of the open-roofed churches by fire) to render the whole, or as much as possible, of the fabric fire-proof, by vaulted ceilings below the timber roofing. At first they only covered the narrower parts and aisles* in this manner, but gradually extended it to the main avenue or nave. This was first done in Germany, and in the early examples we also find the first change from the round to the *pointed* arch,—generally, but inaccurately, considered the grand distinction between the Romanesque and the *Gothic* styles. The change doubtless arose from ignorance and timidity of construction; but it had a most important artistic effect, by introducing an angle into the arch, and thereby bringing it back almost into a graver class of form than the third, and rendering it more fit for main structural features. The pointed-arch

* As ambiguity sometimes arises from the uncertain meaning of this word *aisle*, (derivable either from *aile* or *allee*,) we shall use it only in the former sense, as applying only to the *lateral* alleys of a building.

buildings, though not attaining (for no arched building ever can attain) the grandeur of the rectangular archless styles, yet have a higher degree of gravity and severity than the light sweep of the Italian round-arching can ever attain. Compare the interiors of the Lady-chapel at Southwark and the vestibule of Somerset House, and remember that the latter is by far the more massive.*

It is common to date the great transition, from the first appearance of a pointed arch, to the complete disappearance of the last round one. But in truth it extends from the revival of vaulting, (disused since the Roman times) to the universal use of that covering, *i. e.*, to the disappearance of the last lintel, or the last unvaulted space. All Romanesque buildings with vaulting are an approach towards Gothicity; and the building that contains a lintel, however, short, is not completely Gothic. Even at Salisbury there are a few lintels across the narrow galleries and passages. In this continued progress, the change from round to pointed is only one step, and a far less important, and less exactly definable step than another we could name, which is the *unmasking of the buttress.* It is this that makes the grand restoration from falsehood to truth. It is this that distinguishes the beautiful church of Marburg in Hesse, and the more glorious one of Salisbury, (begun a few years earlier, in 1219,) from all previous buildings, and stamps them as the first complete developments of the new system. The buttresses that prop their vaulting appear without disguise.

Vaulting, then, being the all-pervading MOTIVE—the final CAUSE of Gothic architecture,† that to which all its members subserve, for which everything else is contrived, and

* That is, it *represents* a more massive construction. In considering modern English architectural works, it must never be forgotten that they differ from all others in this respect. Foreign architecture (and English before the fall of Gothicity) consists in *fine building*. But English architecture since that period consists in the *representation* of fine building, and its works must (like theatrical scenery) be criticised not as what they *are*, but as what they *represent*.

† This was first shown, we believe, by Ware, in his admirable "Tract on Vaults"

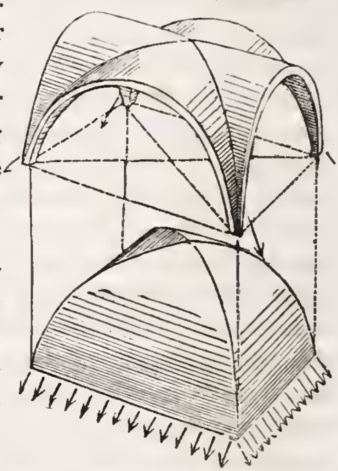
without which the whole apparatns would be aimless and unmeaning—it will be neeessary here, first to take a rapid glanee at that art, then at the modifications it introdueed in the general design, and lastly in the subservient parts of the building.

I. *Of arch or vault work as the fundamental principle of the Gothic system.*

Whether any people before the Romans were in the habit of building arches and vaults, is a qnestion having no bearing ou onr present subjeet ; bnt we must observe that the *dome* is a simpler principle of eonstructiou than the areh—is found in the works of animals (whieh the arch is not), and has been employed by many nations who eould not (or did not) build arehes, as the aneient Mexieans and the present Esquimaux. The aneient Romans, however, (who eoustrueted with briek the largest domes even now in existenee), not only used this kind of eovering, whieh rests on *all sides* of the spaee to be eovered, but also the simple or wagon-head vault, whieh rests on only *two sides* of the eovered reetangle, leaving the other two free from all pressure. But further than this, they were the inventors of that highly ingenious eontrivanee, the *cross-vault*, which exerts its whole pressure solely on the *angles* of the apartment, leaving all the sides free. Its origin may be thus explained : suppose a simply vaulted passage had to be eontinued *across* another exaetly similar passage, lying at right angles to its eourse, and it was required to leave both eorridors perfeetly free. First, suppose them to interpenetrate eaeh other, without omitting any part of either ; the square of interseetion will then be eompletely enelosed by four walls, and eovered by a double ceiling, for eaeh vault by itself eovers this spaee : every point, therefore, in this square is doubly eovered, exeept the points situate along the two diagonals of the plan, for vertieally over these two lines do the two vaults interpenetrate eaeh other. If we eonfine our attention to the lower of the two eeilings thus formed, we shall find it to be a square dome,

for a dome may be erected on a square or any other form of base, and its property is always to rest equally on the whole enclosure : now the four ridges, or (to borrow an expression from carpentry) the *hips* of this square dome, are the common intersection-lines of the two vaults, and are evidently simple elliptic curves in vertical planes : consequently these two semi-ellipses have the property of *arches,* and can support not only themselves, but the whole of the upper ceiling. Hence the lower ceiling or square dome may be entirely removed, as well as the four walls on which it rests, leaving both passages open, and the cross-way completely covered by a ceiling that rests solely on the four angles : it is even independent of the vaults over the four arms of the cross, which may be entirely removed, leaving the cross-vault to be confined solely by four definite pressures applied diagonally to its four angles.

Square cross vault, resting *upon* and *against* the angles only of its base.



Square dome, resting *upon* and *against* the whole enclosure of its base.

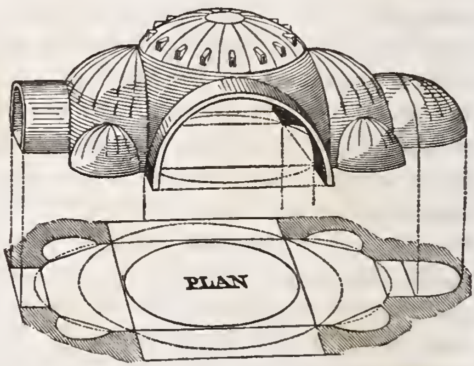
The same elliptic lines which in the square dome formed external ridges, here form internal ridges, called *groins.*

The beauty and advantages of this kind of vaulting led the Romans to use it, not only over a cross-way, where it was necessary, but also over all corridors and long apartments, by dividing them into a series of squares, each covered by a cross-vault, thus throwing the whole pressure of the vaulting on the points of division between these square compartments, and leaving the remainder of the walls free for openings, or to be constructed ever so slightly, or even omitted altogether. The boldness of their constructions of this kind has never been equaled. There is evidence that

the Temple of Peace, now in ruins, had its nave covered by cross-vaults 83 feet wide, so that the groins on which the whole rested had a span of $83 \times \sqrt{2} = 117$ feet; and an apartment in the baths of Diocletian, still in use as a church, has a similar ceiling of about 86 feet in diagonal span still remaining, although it is formed on an unsound principle. The compartments are not square, but rather wider in one direction than the other. Now in this case, either *one* or *both* of the crossing vaults ought to have been *elliptical*, so that both, notwithstanding their unequal spans, might have their springings at the same level, and their crowns also at the same level. The groins would then have been confined to vertical planes over the two diagonals of the compartment. But, in fact, both vaults are made semi-circular, and their crowns being at the same level, their springings are not at the same level. The consequence is, that the intersection lines or groins are lines of double curvature, and not being in vertical planes, are not therefore true arches, and would not be able to support themselves, were it not for the immense and wasteful thickness of the vaulting, containing several times more material than is necessary. Moreover, curves of double curvature are invariably displeasing in architecture, for the eye cannot readily understand them.

With the decline of Roman power, this art of vaulting was lost, and for centuries the basilicas of Italy and the churches of all Roman Christendom remained with nothing but timber roofs. The Greeks, however, retained (or else re-invented) another mode of vaulting possessing many of the advantages of groining, but not all of them. This system depended on two simple geometrical principles: 1st, that every section of a sphere by a plane is circular; and 2dly, that every intersection of two spheres is a plane curve, and therefore circular. The Greek vaulting, then, consists wholly of spherical surfaces, as the Roman consisted wholly of cylindrical ones. A hemispherical dome may be supposed, whose base circumscribes the plan of any apartment or com-

partment, square, rectangular, triangular, or polygonal. Now imagine the sides of this plan continued upwards, as vertical planes, till they meet the hemispheric surface. This meeting-line must in every case be a semi-circle, and may therefore be made an open arch ; and the portions of the dome thus cut off from every side of its base may be omitted altogether, provided their office as buttresses to the remaining portion above be replaced by the pressure of some other vault, which may be of any kind, if it be applied against the semi-circular arch. Thus no walls are required on the sides of the supposed compartment, all the weight of the *pendentive* dome (as it is called) being thrown on the angles of its plan. Thus this dome serves for covering an open cross-way, and is so applied at Sancta Sophia, of which the covered cross-way, 115 feet square, might well be esteemed, in the barbarous age of its erection, a wonder of the world ; and the same idea repeated without end,—the same sprouting of domes out of domes,—continues to characterize the Byzantine style, both in Greek churches and Turkish mosques, down to the present day. They have been well described by Hope as a congeries of globes of various sizes growing one out of another.



Vaulting of Sancta Sophia : the dome over the central square resting *upon* its angles, but *against* its sides.

This system of vaulting has been adopted by two great modern architects,—by Sir C. Wren at St. Paul's, and by Soufflot at St. Geneviève, Paris ; by the former with great success, and in both made to harmonize well with the Roman style. But observe the inferiority of this to the Roman

cross-vault. The latter is, as we have seen, independent of the four adjoining vaults, over the arms of the cross. But the pendentive dome cannot subsist without them ; for though its *downward* pressure is confined to the angles of the plan, its *outward* push is exerted against the sides,—though it rest *upon* four points only, it rests *against* innumerable points, viz., against the whole semi-circle of each of the main arches. But the cross-vault has its whole pressure,—not only its weight, but its push,—collected into four definite resultants applied to the angles only, so that it might be entirely supported by four flying buttresses, no matter how slender, provided they were placed in the right directions to transmit these four simple resultant pressures, and strong enough not to be crushed by them.

At the first dawn of Gothic science, when the numerous and disastrous fires among sacred edifices led to the attempt (first perhaps in the Rhine valley) to vault them with stone, a mixture of the Roman and Eastern methods seems first to to have been tried, and some curious combinations of this kind are still to be seen in the old churches of Cologne and its neighborhood. The superiority of the Roman system, however, soon led to its exclusive adoption, and it is to be seen in the crypts and aisles of many buildings of our own country, as in those of the naves at Durham and Ely and the transepts at Ely and Winchester ; but in extending this kind of ceiling to the central avenue, many difficulties arose, not perhaps so much from the increased span and height above the ground, as from the oblong form of the compartments, (those of the aisles having been square ;) for the builders of this age very properly rejected the doubly-curved groins of Diocletian's baths, which indeed would have been quite impracticable over a plan differing considerably from a square. Various expedients were resorted to, and the only successful one for vaulting the clerestory with *round* arches alone, was by making its comparments square, and letting each correspond to *two* compartments of the side aisle. This is the mode

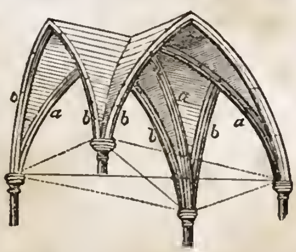
adopted at the three great Romanesque cathedrals of Worms, Mentz, and Speyer (in the last of which, the diagonal or groin span is more than 60 feet), and in the two great abbeys founded by William I. and his Queen, at Caen ; and it seems to have been intended, but never executed, in the nave at Durham. We have no example however, in England, of a nave with round-arched vaulting, if we except the small massive chapel in the White Tower, London, which is a simple vault without groins, and is not a *clear* story, but enclosed between upper aisles, so that there is no difficulty as regards its abutments. But the various attempts to overcome these difficulties would hardly fail to lead, first to the mixture of pointed vaults with round ones, as in the Rhenish churches, and then to the exclusive use of the pointed form. Without detailing the various modes in which this might happen, and did happen, as appears from the various interesting expedients seen in those buildings,* we may observe that, as the chief practical difficulties attached themselves to the upper and horizontal portions of the round vaults, nothing could be more natural (in an age unfettered by pedantic admiration of classical precedents) than to get rid of these difficult and hazardous parts of the work, by beginning each foot of the arch as if it were meant for an arch of wider span, so that the two curves might meet, before attaining the horizontality which was dreaded in the crown of the round vaulting.

The Romans had strengthened their vaults with simicircularly-arched ribs, *i. e.*, portions thicker than the rest of the vault, and appearing inwardly as flat bands projecting slightly from the inner surface, and harmonizing well with the similar forms of pilasters in the walls ; but they did not place these ribs where they were most needed, viz., along the elliptic groins, which bear all the rest of the ceiling. The early Freemasons took care to strengthen these important lines, and (on the same principle that modern joists are

* Whewell's 'Architectural Notes on German Churches.'

made deep and narrow) they gradually converted the broad, shallow Roman band into a deep narrow rib, by first simply diminishing its width and increasing its projection or depth, then chamfering the edges till its section became a semi-octagon, (as may be seen in the *newer* Romanesque portions of Winchester transept, but not in the older portions, which are examples of the Roman manner, unaltered.) They also *beaded* the two edges of the rib, and then enlarged these beads till the whole became a *double roll* with a mere fillet between them, whence the transition is easy to the deeper and more variously moulded vault-ribs of the Early and Complete Gothic.

But, meanwhile, important improvements were made in the general forms of the vaulting, till a new principle, very different from that of the Romans, was established. We should observe that the interpenetration of two pointed vaults (as well as of two round ones) could only produce elliptical lines, or else lines of double curvature, (for two cylindrical surfaces can intersect in no plane curve except an ellipse,) yet the early Gothic architects rarely made their groin-ribs elliptical, and never deviating from a vertical plane. These ribs were usually simple pointed arches (of circular curvature,) thrown diagonally across the space to be groined ; and the four arches over the sides of this space were equally simple, the only care being that all these arches should have their vertices at the same level. The shell of the vault, therefore, between these ribs was no regular geometric surface, but simply such as might have been formed by laths laid across from rib to rib. This shell is often no more than six inches thick, while Roman vaults of the same span would have been three or four feet.



Compartment of the simplest Gothic vaulting: *a a a*, groin-ribs; *b b b b b b*, side-ribs or arches bounding the compartment.

The difference of principle, then, was that the Romans

made their vault-*surfaces* geometrically regular, and left the *groins* to take their chance; while the early Freemasons made their *groins* (*i. e.*, ribs) geometrically regular, and let the intermediate *surfaces* take their chance. This was a vast improvement both in construction and in art; constructively, because the groins are really the supporters of the whole work; and artistically, because the eye takes cognizance of *lines*, not surfaces; and while it is offended by the double curvature of the groins in Diocletian's baths, it scarcely detects the winding and irregular forms of the Gothic vault-surfaces.

We need hardly observe that these winding surfaces were not formed of cut stone but of stucco, the shell itself being merely a rubble-work of the lightest minerals to be had, or, in this country, chalk.* The Byzantines, long before, had diminished the thrust of their domes by building them of pumice-stone, hollow bricks, or pots (a practice revived by that excellent master of construction, Sir J. Soane); and a similar motive led to the adoption of the material called by monkish writers *tophus*, volcanic.

The English masons, who, during the Romanesque period, had been but timid followers of the continental ones, be-

* This economical mode of vaulting has now fallen into disuse; but it was applied with perfect success, in 1819, in constructing a pointed vault of the simplest kind, over the Romanesque nave of Christchurch, Hants, the diagonal span being about 31 feet. The Gothic masons, however, at least in this country, seem to have feared its application to works with a wider groin-span than 40 feet; for in this manner are constructed the ceilings of all the English cathedrals, with two exceptions, York and Winchester, which have somewhat wider diagonal spans than the rest. The nave vaults of Winchester are entirely of cut stone, like those of the famous chapels at Ely and Cambridge, and (without the frittered panelling of the latter) are not inferior in beauty and extent to any work of the kind; but the choir of the same cathedral, and the whole of York, have sham vaults of wood and plaster,—the only instances, perhaps, of Gothic deception. At present, such deceptions are the only vaultings made. Their uselessness is shown by the two disastrous fires at York Minster, now said to be 'restored,' that is, prepared for a third conflagration. Many other cathedral roofs have caught fire, but sustained hardly any damage, all supply of air from below being cut off by the fire-proof ceiling. The duomo at Milan, the abbey of Batalha, and Redcliffe church, Bristol, have fire-proof *roofs* as well as ceilings; so that the two former are permanent, undecaying structures, and the latter would be so, but for the badness of its stone.

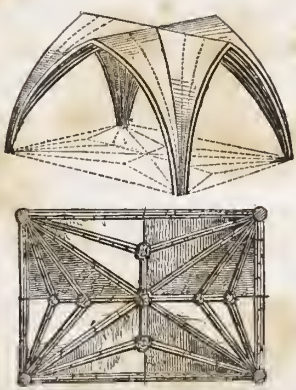
TEMPLE OF JUPITER OLYMPUS.

page 272

came, during the Gothic period, their masters, and constructed many vaultings which for beauty and geometric perfection have no parallel abroad. Indeed, the defect of the winding surfaces, though carried to a great extent in the boldest foreign vaultings, seems to have been hardly tolerated in England,—being here confined to the earliest works, as Salisbury cathedral. In the next step, the groin-ribs were elliptical, as in the choir of the Temple church ; and hence, when, in approaching the complete Gothic, intermediate ribs were inserted between these and the original arches over the sides of the plan (as in the south and west sides of Westminster abbey cloisters,) these ribs also had elliptical curvatures different from those of the groins, in order that the vault of cut stone built upon them might have a regular cylindrical surface.*

It was well observed, however, by Ware, that "the Romans, the Byzantine Greeks, the Freemasons, and the modern bridge-builders, successively tried the ellipse in architec-

* In these cases, as each pair of ribs that meet at a point not over the centre of the plan, form a *leaning arch*, tending to fall towards the centre, this tendency has to be resisted by a *ridge-rib* extending from the centre to the junction of the last pair next the side of the plan ; but there is no reason for its extending quite to the side arch, though it usually does so in England. In the annexed figure, the ridge-ribs are shown, as in foreign examples, continued no farther than is necessary. In England, intermediate ribs and ridge-ribs appeared in the later Early English (as at Westminster,) and became quite general in the Mid-Gothic (as at Exeter, Lincoln, and Litchfield;) but abroad, these features are confined to the declining Gothic,—not appearing till at least a century later than with us.



Compartment of vaulting, with ribs of *six* different curvatures ; viz., *groin* ribs, two kinds of *side* ribs, of *formerets*, one *intermediate* rib or *tierceron* on the wide vault, and two on the narrow vault. Whichever of these six be made circular, the remaining five must be elliptical, if the surfaces are cylindrical.

Litchfield Cathedral

ture, and rejected it." The trial which the Gothic masons gave it was exceedingly short, and has accordingly escaped the notice of many inquirers; but however few the examples of Early English elliptic groining may be, we must not pass over so important a link in the history of the style.

The elliptic groin-rib seems to have been first tried a short time previous to the invention of the intermediate or *tierceron* ribs,* and to have been abandoned very soon after that invention; and I think the examples containing elliptic curves will be found to present generally another peculiarity, viz., that the courses of the masonry all run *horizontally;* while in both the preceding and succeeding examples, they take, between each pair of ribs, a position equally inclined to the two ribs; so that, meeting the ridge-piece obliquely, they are received by a number of saw-like teeth cut in its sides.

Thus the abandonment of *simple circular* ribs for *elliptic* ones was an improvement, and the rejection of elliptic for *false elliptic*, or *compound circular* ones, was a further improvement, as was indeed every change in the general form of vaults, down to the very latest examples, but it was otherwise with their decoration. This, like the decoration of all the other features, attained its artistic culminating point during the fourteenth century, and during the prevalence of this pseudo-elliptic method of rib-drawing.

In the formation of the compound circular ribs, three conditions had to be observed,—1st, that the change from one radius to another should be effected without an angle, *i. e.*,

* The French have preserved some of the old names of the chief vaulting features, among which *tierceron*, applied to an intermediate rib between the groin and the side of the compartment, and *formeret* to the ribs *forming* or enclosing each main compartment, seem useful. In England, the ridge-rib preceded the tierceron, for we find it in Salisbury chapter-house and the chancel and transept of Westminster; while the tierceron appears only in the nave of that building In both these examples, a refined taste led to making the ridge feature quite different from the ribs, because, being not a support but a pendent load, it required delicacy instead of strength, and therefore consists not of mouldings, but (at Salisbury wholly, and at Westminster partly,) of undercut foliage. The later practice of making it represent a rib is a falsehood, when there are no tiercerons or leaning arches to be distended by it Without them it is a mere ornament

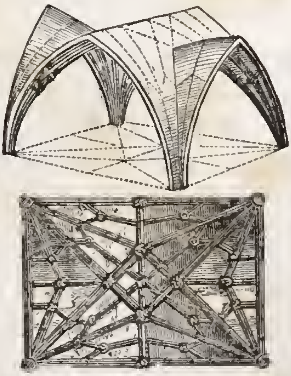
that the two arcs should have a common tangent at the point where this change occurs ;—2ndly, that the feet of all the ribs should have the same radius, and, in fact, be exactly similar up to the level at which they completely separate from each other ; for otherwise this separation would occur at different heights between different ribs, which has a very bad effect ;*—3rdly, that from this point upwards their curvatures should be so adjusted as to make them all meet their fellows at the same horizontal plane, so that all the ridges of the vault may be on one level.†

The pseudo-elliptic vaultings are more pleasing than the truly elliptic ones, on account of the greater variety arising from the plain portions not forming parts of one continued surface ; so that no rib can strictly be called a *surface-rib*, though that name is commonly given to all except the groins, ridge-ribs, and wall-ribs or formerets next the wall.

But the geometrical nicety, not to say difficulty, of such

* This precaution was equally necessary in the case of the elliptic ribs, and is observed most accurately in the vaulting of the Dean's Yard passage above mentioned, which, though simple, is a most splendid piece of architectural geometry. In the clumsy contrivances preceding this, the ribs sprung from the capital, not only with different curvatures, but with different inclinations, the centres of some or all being lower than the springing. Afterwards this was not allowed. A condition was imposed first, that they should all spring *vertically*, and then, all *with equal radii*. The problems thus arising, rendered a single rib a work of more thought, than a whole building, to many modern architects.

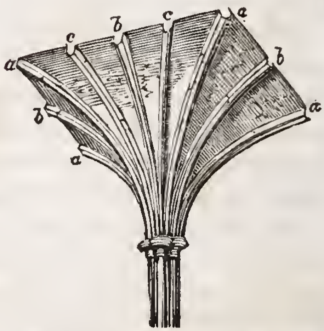
† When they are not at the same level, either the ridges must have a domical rise (as in most foreign examples,) which gives them a push against the enclosing arches, as at St. Sophia, and is therefore objectionable; or else the lower vault, if it have a level ridge, will at its intersection with the side of the higher, form a leaning arch (called a *Welsh* arch,) which is supported by the ribs above its vortex. This construction was not common in the pure Gothic, though examples occur in the beautiful domed kitchen at Durham, and in Winchester cathedral nave ; in the latter unnecessarily, for the side arches rise as high as the main vault, but their ridges *descend* towards it,—a decided defect, as it causes them to push inwards against its haunches or weakest parts.



Winchester vaulting (bird's eye view and plan of one compartment.)

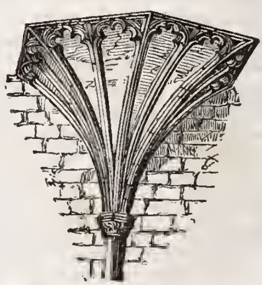
works, led, in the fifteenth century, to a simplification of their general form, yet admitting of indefinite increase in the decoration. This was the beautiful invention of what is called *fan-tracery vaulting*, (very improperly, for a fan-like arrangement of ribs may be, and often is, applied to the surface of any kind of vault.)

This invention might properly be termed *palm* vaulting, or geometrically, the *conoidal* or concavo-convex vaulting. This regularity is shown in the engraving, where it will be observed that the portion of vault springing from each pillar, has the form of an inverted concave-sided *pyramid*, its horizontal section at every level being square or rectangular.



Rectangular Vaulting-pyramid
a a a a, groin-ribs.
b b b, formerets.
c c, tiercerons

This improvement, not yet developed fully, is shown in these engravings, the first of which is a view of the porch of St. Sepulchre New-at , gate, and the next of a porch at Guildhall.

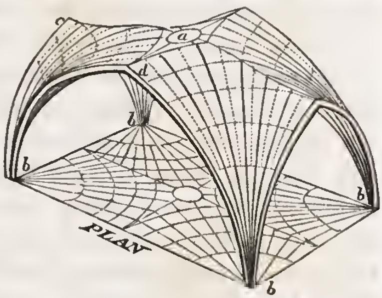


Hexagonal Vaulting-pyramid, imperfectly developed.
St. Sepulchre, Newgate

In the above example (St. Sepulchre) it will be observed that the ribs, rising all to an equal height, have a lozenge of flat ceiling in the centre of each compartment, and

Vaulting–conoid, with all its ribs of equal curvature.

this space would be larger in the more perfect development of this method. Hence on a large scale it is necessary that the space should be domed, and this is most consistently done by simply continuing the ribs with unaltered curvature, till they meet and form two ridges, as in the early vaultings, with this difference, that here, as the ribs have all the same radius and different lengths, they must all rise to different heights before meeting, so that the ridges are not *level*, as in the early vaulting, but gradually descend every way from the centre point, which is the highest in the vault. These arches, described from four centres, soon found their way from the vaulting into all other parts of the building, and became a distinctive style called *Tudor*.

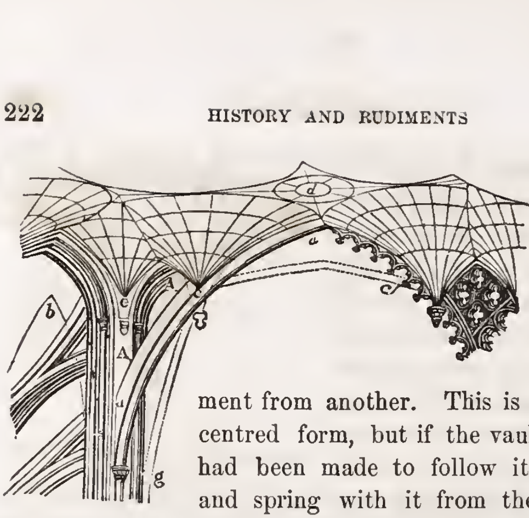


Conoidal-vaulting, King's College chapel, Cambridge, (skeleton lines of one compartment.)

The Tudor, or four centred arch, is not necessarily flat or depressed. Its chief advantages are, that it can be made of any proportion, high or low, and always with a decided angle at the vortex ; whereas the common Gothic must always be of a higher proportion than a semi-circle.

From this style arose the "depressed Tudor," with the aspiring lines of the Gothic, and the peculiarities of the Tudor.

The essential parts of one quarter of a compartment are shown towards the left hand of the accompanying figure. It



will be seen that the whole rests on the great arch *a a*, dividing one compartment from another. This is of the two-centred form, but if the vaulted conoids had been made to follow its curvature, and spring with it from the same origin, they would obviously so intersect as to leave for the clerestory window nothing but the small, inconvenient, lancet-formed space, shown by the dotted lines at *b*. To gain height and space, therefore, for these windows, the main conoids are made to spring, not from the foot of the arch *a*, but from a point *c*, about half-way up its curve ; and the ribs diverging thence in every direction, form, of course, not merely half but *entire* conoids and it is no small advantage that the lateral thrusts of all these ribs destroy each other : but their downward pressure, embracing the collected weight of nearly the whole ceiling, concentrated on the two points *c c* of each arch, is a serious defect with the present form of arch, for it properly demands an arch with cusps at *c c*, as well as at the vortex ; and though the *three-pointed* arch thus formed might be unpleasing in ordinary situations, it would be beautiful here, because statically correct.* It might have been obtained without interfering with the general design, either by bringing up a highly inclined rib from some

* This property of arches (by which each pressure concentrated on a point calls for a cusp at that point, and each cusp calls for a concentration of pressure on it,) may be shown by the *catenary*, which becomes an inverted Gothic arch whenever a weight is suspended from one link. Hooke's discovery, "ut pendet continuum flexile, sic stabit contiguum rigidum inversum," is a motto never to be forgotten in Gothic building. A French street lamp, or a spider's web, may thus teach the architect important lessons ; and perhaps the equilibrium of some of the boldest vaultings was insured by experiments on systems of chains representing the ribs inverted.

point below g, to give additional support to the point c, or else by throwing a flat arch across from c to c, whose lateral thrust, by combining with the downward pressure on theso points, would turn the resultant more aside, into the body of the rib a.

The variety of curvature in compound arches often gives them a peculiar grace.* But the "depressed" Tudor arch is not a *necessary* adjunct to conoidal vaulting, and the gorgeous chapel of Henry VII. presents us (if we can look through the disguise of meretricious ornament) with a noble attempt to combine the advantages of this vaulting with the aspiring expression and small lateral thrust of the high two-centred arch.† The singularly complex vaulting over the clerestory of this chapel, seldom rightly understood, becomes, when divested of its inessential parts, quite intelligible, if we remember the architect's object, to combine the most recent constructive science with the artistic expression of an earlier style, and this in the face of a great difficulty, arising from the unusually oblong plan of the compartment (nearly thrice as long as its breadth), which, if treated by the Cambridge method, would have required an exceedingly depressed arch, hardly practicable, or at least, by its great lateral thrust, requiring most clumsy expedients on the outside for its abutments.

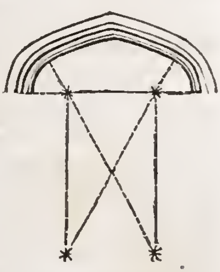
---

* The three following points should be attended to in these arches:

1. Their effect mainly depends on the angular extent of the lower curve, which, in good examples is not more than 65°, nor less than 45°.

2. The radius of the upper curve varies from *twice* to more than *six times* the radius of the lower; but generally speaking, the greater their disproportion, the more obvious, and therefore the less pleasing, is the sudden change of curvature.

3. It was a common (but not a general) rule to place the lower centres vertically below the upper and opposite ones thus:



Four-centred arch.

† Since writing this, I have seen two other examples of this most refined vault-work, in the Cathedral and Divinity School at Oxford. They are all three nearly contemporary, so that the priority of the invention may be doubtful.

But to return, the conoids springing from *c c* would suffice to cover the whole plan, but the semi-arches formed between them and the wall would have been far from pleasing, besides exerting a push against the top of the wall, where it could not be conveniently resisted (because not collected into a single resultant.) The conoids are therefore opposed by corresponding half-conoids springing from between the window-heads at *e*, and to meet their outward thrust, an additional range of flying buttresses is provided, above the common or lower range, which take the thrust of the arches *a*. The two flying buttresses are distinct, though connected by a web of open tracery, which also fills the space A A.

So far, if the constructive principles of this ceiling had been displayed, instead of disguised, it would (whether much or little ornamented) have been as much admired, and perhaps imitated, as it has actually been wondered at and condemned. But the disguise may be thus accounted for: as the ribs of the conoids and half-conoids do not spring vertically from their origins at *c* and *e*, their intersection would form a segmental arch (with angles at its springing); but this not being a graceful form of window-head, its angles are rounded off, and to correspond with this and leave no portion of the wall unoccupied, the half-conoids are prolonged downwards into the form shown in dots at *e*. But uniformity was carried too far in making the main conoids, *c*, assume the same form, for this gives them (as shown at *c*) the air of huge pendents, for which, indeed, they are often mistaken.* It is needless to say that the only real pendents are those hanging from the centre of each compartment, as from *d*;

* Another unfortunate disguise arises from the foliation applied to the rib *a*, which reduces that important member to apparent insignificance. Where strength is required, it should not only exist, but *appear*. Bold and simple mouldings should have sufficed for the decoration of the main stem, which so beautifully, like the leaf-stalk of the fan-palm, supports its spreading burden, from which the artist might also have learned the necessity of an angular bend at *c*. The pliancy of the vegetable structure and the brittle rigidity of the stone do not, in this respect, lead to different constructive principles, since the *tendency* in the former, and the *aim* in the latter, are alike—to avoid all but *compressile* forces.

and these, which occur also in the same situation in the aisles of this building, at St. George's chapel, Windsor, and in many foreign buildings of an earlier date, are not, as many suppose, useless excrescences: they serve, like the ridge-ribs and bosses of a purer style, to supply that load on the vortex which the equilibrium of the pointed arch not only admits, but requires. The abuse of these members arose when they were formed into the semblance of ribbed and paneled conoids,—features of support, apparently pointing to (and therefore demanding) supports from below.

II. *On the general plans.*—Before proceeding to examine the other parts of the Gothic system, it is necessary to glance at the peculiarities of its buildings in general plan and outline. These, though all derived from the well-known basilica, will be found to present many differences rather depending on *place* than time. There have been plans peculiar to certain countries and even provinces; and these peculiarities seem to have maintained their ground for centuries, unaffected by the changes in decorative style. Thus the churches with two chancels, and those with a transept near each end, are peculiar to Germany; those with two transepts near the centre, to England; and double or dipteral aisles are a southern feature hardly to be found north of Paris. So also the apse, (*i. e.*, semi-circular or semi-polygonal termination,) which was always universal, or very nearly so, on the Continent, is rather an exception than a rule in England; while the central tower or lantern, so generally and largely developed in England and Normandy, hardly occurs in the rest of France. Towers detached from the church are almost confined to Italy; and pairs of towers in the rentrant angles (a very beautiful feature common over eastern Europe) hardly advanced west of the Rhine.

Some Eastern peculiarities of form, as the square and short cross plans, were introduced by Greeks into the Adriatic side of Italy, but spread no further, because the Romish ritual involving processions required lengthy

churches, avenues, and aisles. No such reasons, however, can be given for the other local peculiarities of plan, which must be referred to the peculiar tastes of different nations.

The inventive fancy of the Germans seems to have led them to try, during the Romanesque period, every possible combination of form consistent with great length and the cruciform plan ; or else the durability of their stone has preserved to us a greater number of these early experiments in Germany than elsewhere. Several of the oldest churches of Cologne, (St. Mary in the Capitol, St. Martin, and the Apostelnkirche,) as also St. Quirin, at Neuss, and the noble early pointed church at Marburg, present a plan which, though classed among Latin crosses, seems to form a link between them and the Greek. The latter term is applied to a cross with all its limbs nearly equal, and generally very short, while the form now spoken of has *three* limbs equal and similar ; but the fourth, which forms the entrance, is considerably lengthened.* This form is exceedingly uncommon away from Cologne, though it is the plan of the two greatest cathedrals of Italy, (that at Florence and the mod-

* All lengthy crosses are called Latin. There are several varieties arising from the gradual lengthening of the eastern or chancel limb, which, from being at first the shortest, became at length in some English examples the longest. We may distinguish—1st, The original Latin cross, resembling a crucifix, the limb of entrance being the longest, and that opposite the entrance the shortest. The grandest example is the cathedral of Pisa, and this is also the form of the *clerestory* in the ancient basilicas ; but their numerous aisles fill out the nave to an equal breadth with the transept, thus obliterating all cruciform appearance in the ground plan. The second kind of Latin cross is that described above, formed by lengthening the chancel, and making both it and the northern and southern arms all similar. 3dly, The beautiful symmetry of this plan was destroyed by still further lengthening the eastern limb, though still keeping it shorter than the nave. Examples are abundant in every country : the greatest are Milan and Rheims ; in England, Ely and Norwich. 4thly, The symmetry was restored by making the eastern and western arms equal, as at Amiens and Salisbury, the spires of which are in the centres of their length as well as breadth. This is the commonest Gothic form, but its symmetry of plan does not appear in the side view, because of the low chapels forming the east end. The continuation of the clerestory to the extreme end seems peculiar to England, and is very rare in large buildings : Ely, Lincoln, and York cathedrals are examples, but at the latter the eastern limb is rather longer than the western—a defect common in the English double-cross churches

ern Vatican,) having arisen in the latter case from the addition of a long nave to what was originally intended to be a Greek cross. In all these cases the three short limbs are either terminated by, or wholly consist of, three apses.

Many of the Romanesque churches of the Rhine present an extension of this plan by forming a cross of this kind at *each* end of a long nave, of which the finest example is the Apostelnkirche. Hence arose the German double cross, very different from the English, and resembling rather this figure, ‡. The two transepts, however, were never alike: one of them, generally the western, has square ends instead of apses; frequently both are square-ended, but the extreme ends of the building were in many cases, as at Mentz, both apsidal, forming two chancels, and admiting of no entrance in the axis of the building, but only in its sides, (as at Worms and Oppenheim,) or on each side of the western apse, (as at the very curious abbey of Laach.)

In later buildings the western apse was omitted, but the eastern always retained, and occasionally it was flanked by two minor apses projecting from the eastern sides of the transept arms. This arrangement occurs in France at Rouen cathedral, and in England at Romsey, Hants; but in Germany it seems common, the best known examples being Laach, Andernach, and Gelnhausen. In the latter, the side apses are carried up to form towers. This triapsal plan, far inferior in beauty to that above described in the Cologne churches, arose from the then newly-introduced custom of *orientation*, or placing every altar against an eastern wall; whence also the practice of giving transepts an aisle on their east side only, destroying the symmetry of their end façades, as at Salisbury.

Sometimes a transept projected so little as to appear only in the clerestory, and not to affect the ground plan, as is the case with the lesser transept at the abbey of Heisterbach, and the only one at Freiburg minster, both of the Transition or earliest Pointed period. Both of these transepts, how-

ever, are lower than the clerestory, though higher than the aisles, which is a great detriment to the unity of the building. The transept of Notre-Dame at Paris, and the lesser one at York, are of the same kind, but, being as high as the main building, are free from this objection.

The German Romanesque churches are not more remarkable for these varieties of plan, than for similar complexities of outline produced by their numerous towers, amounting in some cases to *six*, and at the small cathedral of Limburg to *seven*. The crossing of each transept had usually a low square tower concealed by the roofs ; four arches thrown across the angles of this, served to support the oblique walls of an octagonal lantern rising above the roofs, and terminating internally by a cupola, externally by a pyramidal roof, pitched at an angle of 60°, or more. The western tower, however, (whether placed over the crossing of the west transept, or at the extreme west end,) was usually without an octagon, and ended in a *square* pyramidal roof, the sides of which correspond to the angles of the tower, and, by intersecting its sides, form four high-pitched gables. This form of tower-roof is a striking characteristic of the older German churches.*

Small towers or turrets were placed in pairs, first, near the east end only, as at the Apostelnkirche ; then near both ends, as at Speyer, Mentz, and Laach ; and finally, at the west only, as in most Gothic churches, where they assume greater importance, and become (at least on the Continent) the principal towers both for size and height. When there were two towers at each end, the two pairs were always varied in form, height, and distance asunder. Thus, at Laach, the *octagonal* eastern lantern is flanked by *square* towers, and the *square* western one by *octagonal* towers: the latter are placed as far apart as possible, viz., at the ex-

* According to some engravings it seems to be in some cases octagonal, with an angle over each angle of the square tower, but they are often unintelligible or irreconcilable. Even in Moller's fine work there are discrepancies in this respect (See his Plates of Limburg cathedral.)

tremities of the western transept, while the former are as near as possible, viz., in the eastern rentrant angles—a position common in the oldest German buildings, and which gives to the eastern view of the Apostelnkirche a Byzantine and almost mosque-like character. All these towers terminate in pyramids or spires.

The seven towers of Limburg consist of a central octagon and spire, two large square western towers, with gable pyramids,* and four slender ones of the same kind, at the extreme corners of the transept,—a rather unusual position. Such towers, however, occur in the great Gothic cathedrals of Rouen and Rheims ;† and there is good evidence that they formerly existed in the Saxon transept ends of Winchester, but were removed probably in the alterations of 1079. Historic mention is made of a tower or towers, also at the east end of that immense Romanesque pile, which must have been hardly inferior to that of Speyer.

There are also instances of pairs of towers so attached on each side of the church as to form themselves a transept. This occurs sometimes at the west front in all countries, as at Rouen cathedral, Lincoln, and Wells. Again, two buildings on the extreme confines of the Gothic sway,‡ perhaps the easternmost and westernmost examples of pure Gothic, agree in one great peculiarity. Exeter and Vienna present instances of the only transept being formed by two towers built against the sides of the church.

---

* A convenient name for the form of roof above described.

† These towers possess, both at Rouen and Rheims, a peculiar and rather elegant character. They rise no higher than the main roof, are less ornate than the rest of the building, and have each face occupied by one lofty unglazed window, or open arch, divided into two lights by a very slender shaft.

‡ The geographical range of the Gothic style cannot be very exactly defined, owing to the habit which eastern travelers have, of calling everything that contains a pointed arch, Gothic. It seems, however, to extend as far S. E., as Corfu, or perhaps Rhodes, and N. W., to Ireland ; N. E., to the Baltic Isle of Gottland, and S. W., to the oceanic isle of Madeira, where the extravagantly debased niches of the cathedral of Funchal furnish (in the first modern colony) the last expiring effort of mediæval art : geographically placed between two worlds, it seems fitly to stand between two historical epochs.

The Gothic buildings of *France,* though more magnificent, present less variety of form, and far less *external* beauty, than those of either Germany or England. Their comparison with the latter shows some great differences in general design, which we will endeavor to trace.

The year 1219 is remarkable for the foundation of two cathedrals of the largest class, one in France the other in England—Amiens cathedral and Salisbury cathedral; one French Gothic, the other English. Our limits forbid a comparison of their respective merits.

We should observe, that the churches of Normandy (especially the three magnificent ones at Rouen) approach the English rather than the French type. They exhibit their lengthy proportions, (every other dimension seeming sacrificed to lineal extent,) their strongly marked transept and outer buttresses, and their great central feature predominating over the western towers, which in France were generally the principal ones. Normandy seems always to have formed architecturally an English province; and the observer who goes from Westminster to Rouen, goes from a French building to English ones.

The greater proportion of height to breadth in the French Gothic avenues is not a general feature; the great majority of such vistas, in all countries alike, having the height equal to twice the breadth. A higher proportion is confined to buildings of the largest class; for the larger they are, the greater may this proportion be without appearing excessive.

It might be supposed that the introduction of arching, by enabling *wider* spaces to be covered than by lintels, while at the same time it required more extent of abutment (for the same width of span), the higher it was raised above the ground would for both these reasons have led to openings of a lower and wider proportion, both in windows, arches, avenues, and entire buildings. But this was not the case, at least not in ecclesiastical buildings, the designers of which continued to be fully alive to the majesty of tall proportions,

even when obtained at the expense of space and convenience ; and they never, till the latest period of the style, admitted archways for any purpose, great or small, lower than twice their breadth This was also the proportion given to *single* openings by the classical ancients, not only in doors and windows, but in distyle porticoes (as those of the Tower of the Winds.) But it seems to have often escaped notice, that in both systems the placing of several openings side by side (at least externally) renders a taller form necessary, and this in proportion to their number. A tetrastyle portico formed simply by the extension of the distyle, would be low and squat ; it requires to be nearly square in its general outline, *i, e.*, the height of its openings must be about thrice their breadth. A hexastyle portico requires the columns to be placed still nearer than a tetrastyle, as appears plainly from comparing the two porticoes of the Erechtheum. But two columns taken out from either of these, especially the hexastyle, would be quite inapplicable as a distyle porch, the opening being much too narrow. The prevailing faults of the *English* Gothic is lowness of proportion.

The whole internal portions of Amiens are so admirable, that this model was closely followed in two other immense edifices, each intended to have exceeded every human work, but, after centuries of labor, left not half complete. Beauvais remains a choir and transept only ; Cologne a mere choir. The first of these glorious fragments, while preserving the proportions of its model very exactly, exceeds it in scale by about one-sixth : while Cologne would have been, internally, almost a copy of Amiens, all the modular dimensions differing only by a few inches. The German cathedral, however, besides the advantage of a more complete style, would have had a strongly marked transept, advancing *four equal* compartments each way, a stone central tower and pyramid of a breadth proportioned to the building, and two colossal western towers and spires as high as its whole length, and so adjusted that a straight line might be drawn

from their summit, touching that of the central lantern and of the east end. This building, if completed exactly according to the design, would certainly eclipse all others of every age, country and style.

The duomo of Milan, the greatest completed Gothic structure of Italy or perhaps the world, also closely follows Amiens, both in proportions and scale, the chief alteration being that of placing the transept nearer the eastern than the western end.

The buttress-chapels (or else double aisles) of the continental churches called for peculiar modes of roofing. Instead of one *longitudinal* lean-to or semi-roof, there is commonly a separate and complete roof over each compartment, but extending *transversely* over both the inner and outer aisle, and terminating both ways in hips. Such is the case at Cologne, and at the nave and apsis of Amiens, but in the choir they terminate outwardly in gables,—an arrangement which seems more consistent than any other with the Gothic principles. The superb church of St. Ricquier, near Abbeville, presents a singular modification of this. Instead of each roof covering a compartment, it covers two half-compartments, making a gable over each buttress, and a gutter over each window.

As these modes of aisle-roofing do not abut against the central building, they do not necessarily lead to a triforium; and the clerestory windows might be continued quite down to the cornice over the aisle arches. Such is, in fact, the case; but the architects, wishing to retain a kind of triforium, formed the lower part of these windows into a very narrow one, not lighted from within, as with us, but admitting light from without. These galleries are formed, as it were, in the thickness of the wall,—if that can be called a wall which consists only of two fairy-like arcades,—the outer glazed, the inner left open. The shafts of both are of the utmost slenderness, having nothing to support but the walk above, open to the exterior, and the glass of the clerestory

window; and hence there is no wide arch spanning the whole compartment, or at least half of it, as in English triforia. While the *blind* triforium at Abbeville, with tracery and parapets varied in each compartment, is exquisitely beautiful, these *luminous* triforia at Cologne, Amiens, Beauvais, and St. Ouen, by admitting light where we commonly see solid wall or dark openings, produce an effect our Gothic never reached.

Dr. Möller observes, that the Gothic churches of Hesse are mostly without clerestories, but does not say whether their outer roofs all resemble that at Marburg,—an interesting question, as this kind of building (which has its own peculiar style of beauty, and is well adapted to modern wants) is very variously roofed in different countries. At Vienna, one enormous high-pitched roof covers all three avenues, and gives the form of a barn, with more roof than wall. At the east end of Salisbury, a similar roof, but with a moderate pitch, below 45°, is skillfully adjusted at the end to fit three acute gables,—an example well worthy of modern imitation. The more general English method was by three distinct longitudinal roofs, (as at the Temple church,) leaving the intermediate gutters to be choked by every fall of snow. At Marburg, the aisles are covered by transverse roofs over each compartment, originally (now over each pair) proceeding from the central roof, and terminating outwardly in hips.

In the foreign dipteral churches, whether with the outer aisles open or divided into buttress-chapels, these parts were commonly of the same height with the inner aisles. Milan and Beauvais present exceptions to this. They have what may be called a double clerestory, the inner aisles rising above the outer aisles or chapels, and having windows above them. At Milan, the outer aisles are so disproportionately high, that these two clerestories, which are exactly equal and similar, are reduced to a very poor altitude; and the compartments being very broad, the vaulting leaves room in each case for only a very small window under its crown, *i. e.*, in

the centre of each wide compartment. Thus these two tiers of thinly-scattered holes admit only just light enough to destroy the unity of a building with five avenues of equal height ; and this famous duomo has neither the beauty of the common Gothic nor of the Hessian arrangement, but the disadvantages of both, with neither the airy clerestory nor the palm-like combination of pillar and out-branching vault-ribs, which is peculiar to buildings without clerestories. But how differently is this managed at Beauvais, which, though the loftiest apartment ever built, is yet made by its numerous stories, and their skilfully-contrasted inequalities, to appear both inwardly and outwardly loftier than it really is. For within we find, first, the enclosure walls of the outer chapels, then their lofty windows ; above their vaulting a small blank triforium, and then the moderate-sized aisle windows ; again, (above the aisle vaulting,) the great transparent triforium, and then the immense clerestory, with windows longer even than those of the outer tier, and at least ten times the height of the first blank triforium, which yet is (or seems) high enough to form a gallery. A dimension is not increased in appearance by division into *equal* parts, but only into *unequal* ones well contrasted. It is very doubtful whether the uniform repetition of columns, windows, or other features, adds to apparent length ; but the unequal divisions of length formed in a Gothic church by the vestibule, nave, crossing, chancel, &c., give artificial length, and the unequal stories give artificial height, while the *equal* stories of a factory produce no such effect.* This principle of contrasted division is important in the composition of mouldings. In good

* Perhaps a *graduated* division, diminishing upwards, may also give apparent height. No building, of the same altitude, appears nearly so lofty as a Doric portico ; on which Papworth observes—"In the vertical subdivisions of the masses forming the columns, the triglyphs, the metopes, and the mutules, and even the ornaments above them,—the acroteria and terminations of the roof,—it is evident that great attention was paid to produce the effect of altitude, by conducting the eye from the base upward along the columns and entablature, in a succession of lines admirably proportioned to each other, and becoming shorter as they approach the summit of the building."

cornices we never find two members of equal or nearly equal height together, nor should two conspicuous members *of the same kind* be nearly equal, even though separated by numerous members of a different kind. Alteration is as bad as succession of equal parts. There must also be a fixed limit to the principle of contrast where it begins to interfere with that of multitude. There must be a certain disproportion between two divisions which should not be exceeded, because then the larger division would appear greater, divided into two, then entire. What is this limiting ratio ? An examination of the finest classic examples would seem to give, for this limit, the ratio of 10 or 12 to 1. A greater disproportion than this, the eye can hardly measure or understand as a contrast. While very small differences (if visible at all) are always *over*-estimated, very great ones are always *under*-estimated. Good examples of contrasted division should be copied *simply as such.* They are equally applicable to the divisions of a building or of the smallest moulding, conducing alike to sublimity in the one, and beauty in the other.

The origin of the chief peculiarity of general form in the *English* Gothic, viz., the eastern minor transept, may be accounted thus :—In cruciform churches there were two modes of placing the choir and its furniture ; either in the eastern limb, which was most common, or in the centre of the cross. This place was especially proper when there was a lofty lantern over it, as in the Italian duomi and English cathedrals, but not in the French, in which accordingly there seems to be only one example of this arrangement, viz., at Rheims.

This plan had the advantage of placing the choir in the most imposing spot, where alone the whole building displayed itself in five grand perspectives,* but it had the defect of shutting out the view of the transept arms from the nave and from each other, which latter was always the finest

* The fifth being the tower, which was in all these cases originally open as a lantern.

proportioned vista in the building, because not too lengthy for its other dimensions.

There is another peculiarly English variation on the general Gothic plan, which deserves attention, and ought to render the name of Alan de Walsingham preëminent among the few Gothic names that have descended to us. This architect invented the truly masterly expedient of *altogether omitting* the four middle piers for supporting towers, thereby at once forming a noble octagonal central space, distributing the weight of its covering, or lantern, among eight instead of four supporters, greatly diminishing the inward push on each, (because it receives the thrusts of its two abuting arches inclined 135° to each other, instead of 90,°) and, lastly, enabling these piers to be enlarged to any extent in one direction (outwards) without stoping or even contracting any one of six avenues of the church.

This invention is equally applicable to any style, or any mode of construction ;* and if disposed to underrate it on account of its simplicity, we should ask, Why was it never used before ? We might add, why has it never been reïnvented even by the most ingenious modern architects ? In looking over the engraved designs of Palladio, Scamozzi, Vignola, &c., it is wonderful to observe how very nearly they often approached this idea without ever completely reaching it.† Indeed, no example of it seems to have been finished out of England, either in the Gothic or Italian styles,‡—and even in its native land, it lay dormant at Ely

* There is a beautiful instance of its use in lintel construction in the tomb at Mylassa (figured in the "Ionian Antiquities" of the Dilettanti Society.) According to Mr. Fergusson, the same form is common in Indian mausolea. It would thus seem to have been invented thrice, in Ionia, India, and England, at widely different epochs.

† It did not, however, escape those excellent geometers, the Spanish Arabs. Since writing this, I have learnt of a complete vaulted example by them, in a bath at Barcelona.

‡ Most modern Italian churches have the octagon space, but at the expense of the aisle avenues, which are either absent, or blocked up, as at St. Peter's. From a plan which Wiebeking saw in the archives of the cathedral of Bologna, begun 1388, it appears that the Ely octagon was proposed on an immense scale (116

for three centuries. Of its revival, Ware says, "The octagon base, and the vista of the aisles through it, is together an invention not easily allowed even to Sir Christopher Wren." Wren never claimed it; he had native plumes enough without borrowing any. Yet, perhaps, if his uncle had not been Bishop of Ely, St. Pauls, though a fine, would not have been an unique building.

This great man, from the beginning of his career, appreciated the manifold merits of the plan peculiar to his uncle's church, and when called on to repair Westminster abbey, he intended to remodel its centre on this type. Bad details and Italian cornices could well have been tolerated for the sake of such an improvement; especially needed here, not only to fit the building for its present use, (for which it is now, like most Gothic structures, singularly ill adapted,) but also to correct its peculiar defects; which are a want of monumental durability; and an irregularity in the compartments next the crossing, which in the nave are wider, and in the transept narrower, than their regular width. But this improvement remains to be made. At some future day (let us hope, of pure taste,) when the hoary pile grows infirm and full of days, and not only convenience, durability, and beauty, but *safety* also, calls for it, Wren's plan will doubtless be carried out, without the faults of his details.

Disappointed here, however, Wren applied the principle to one of his smallest and cheapest buildings, which consequent-

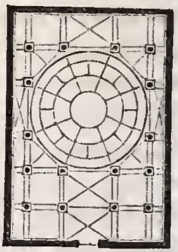
---

feet diameter) for that building, but the cinquecentist architects were too timid to venture on it, for the wooden model in the sacristy adheres to the old method with four central piers; and neither project has suited the resources of "Bologna the Fat," for the nave only is built. The cathedral of Pavia, however, begun in 1489, but equally unfinished, presents the octagon half-developed, and completely so in the original design of its architect, Rocchi. It has been said that the duomo at Florence (left roofless till a council of architects and engineers from all parts of Europe assembled to consult how to cover it) exhibits the rudiment of the English octagon; but, if so, it is very rudimentary indeed. The very ancient little Byzantine chapel of Santa Fosca, on the Isle of Torcello, in the Venetian lagunes, presents a much nearer approach; but in this, as well as in the modern church of Santa Maria della Grazia, at Milan, the resemblance is only in *plan*, no advantage being taken of the octagon for facilitating the covering, which is by a dome, on *four* pendentives only, covering the square.

ly (though only a plaster representation, never yet executed, as it might easily be, in permanent building) has given the narrow lane of Walbrook an European celebrity ;* and

---

* The just and universal approbation bestowed on the interior of this little church, renders it one of the very few modern buildings that furnish proper objects for that search into principles which it has been our study to apply to the chief ancient and mediæval models. In such a search, we cannot but observe, ***first***, that of Sir Christopher Wren's fifty churches, this is, I think, the only one without *galleries*. How greatly, then, must the facility, or rather, the possibility, of designing a fine interior, be diminished by requiring a great portion (often more than half) of its area to be divided into two floors ; when even this great man, in *so many* trials, did not once succeed in solving this problem satisfactorily, or so as to produce an effect approaching to that which he so easily produced, in *one* trial, when unfettered by this most odious requirement of modern parsimony. But, in comparing this church with those few only which can compete with it on fair ground,—those without galleries,—we must still admit its transcendent merit, not only as compared with those of its own style, but also with those of the purest Gothic. We may fairly challenge the production of—1st, any interior, for whatever purpose designed, which produces an equal effect with so small an amount of ornament ; and, 2ndly, any interior which possesses equal beauty with as much fitness for the purpose of Protestant worship. The height being no greater than is necessary for breathing room, a division into *five* avenues was absolutely necessary to obtain any thing like a majestic loftiness of proportion ; yet the number of columns does not impede the sound and sight of the preacher, because this very number enables them to be made smaller than the usual space between the heads of two persons, so that all the congregation can, without loss of space, place themselves so as to see and hear ; for the pulpit and desk are so placed that, if we suppose a lamp lighted in either of them, the shadows of no two columns would overlap to form a broader shadow than that of a single one. But not only are the sixteen columns so distributed as to answer this condition, (fulfilled in hardly any other church ;) they are so arranged in a plain oblong room as entirely to conceal its vulgarity by introducing the various beauties (no where else combined) of the Latin cross, Greek cross, square, octagon, and circle. Observe, too, how strictly the rectangular forms, expressing stability, are kept below ; up to the entablature all is right-angled ; then come the oblique lines, and the elegant circular forms above all. Wren did not (as we remarked in Chap. III) sufficiently observe this principle in some of his works, but here its complete observance so improves the idea, that, though borrowed from a Gothic work, it could hardly be re-transferred into that style without great loss ; for how could the combined plans (cross, square, octagon, and circle) be kept in that style so *equally* prominent as they are here ? none prevailing over and disguising the others. The cross, and especially the square, would hardly appear but for the entablature, which could not be replaced by any Gothic feature that should have sufficient importance without appearing clumsy or unduly exaggerated. Again, that style is so much better adapted to polygonal than to circular plans, that it would be difficult to keep the former from overpowering the latter

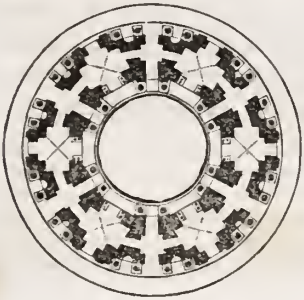


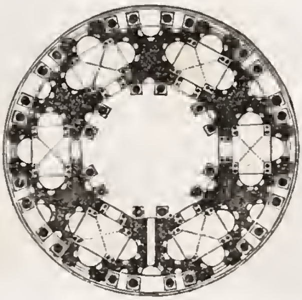
Plan of St Stephen's, Walbrook.

when his first design for his great work was obliged to be abandoned, (it is said with tears,) and the form and proportions of a Gothic cathedral substituted, he recurred to this arrangement as the chief source of its originality and grandeur. Strange to say, this invention, so peculiarly fitted for Protestant worship, which requires an ample central space, (not lengthy avenues,) has slept again for a century and a half, and has only been revived in the elegant church just erected at Highbury.*

* But while the central square of the ordinary Gothic plan is elbowed by its piers, the central octagon, on the contrary, is rather too spacious for the best artistic effect, and at St. Paul's it overpowers the other parts, making the four great avenues seem narrow and low : who would believe that they are as high as those of Salisbury ? A medium, then, between the octagon and the square is presented by the early pointed cathedral of Sienna, which has its central space a *hexagon*, and, though this is there clumsily arranged, and blocks up the aisle vistas, it might by a little change have left all six avenues open and uncontracted. If the middle transept avenue occupied the western half of the hexagon, passing through two of its sides obliquely, then its two other oblique sides might each have a semi-hexagon described on it. The two outer sides of these would form windows ; their two eastern sides, entrances to the choir aisles ; and their two remaining sides to the east aisle of the transept, which might or might not have a western aisle, for that would fall without the hexagon. The breadths between the centres of the columns, (calling that of the nave one,) would be thus. The nave aisles, one-half ; diameter of the hexagon, two ; the central transept, the square root of three-fourths ; and its aisles, one-half of the square root of three-fourths.

The capabilities of the hexagon and dodecagon have been greatly neglected in artistic planning. Their union with square forms would produce many beautiful and useful combinations ;—useful (that is) in *vaulted* and other genuine *permanent* modes of construction ; the chief artistic advantage of which modes is, that they require or conduce to such combinations ; so that, perhaps, elegant planning can hardly be expected, without a return to real architecture. Bartholomew draws attention to the beautiful symmetry of a plan to which the vestibule of the





III. From the general arrangement of the Gothic structures, we must now descend to their details ; first premising that these appeared in a different order in different countries; all of which seem to have advanced by different paths towards the same object, which they all, about the year 1300, completely attained. Not till then did their several styles arrive at the nearest coincidence ; and this only style, *common* to the various Gothic nations, is that which all have agreed to consider the *complete* Gothic, as containing all the essential features of the system, viz. : 1. Universally *pointed arching*, each arch being composed of several ribs or mouldings, so arranged that the innermost or narrowest might serve as centering on which to turn the next, on which a still stronger was turned, &c., greatly economizing the original wooden centre ; 2. *Ribbed-vaulting ;* 3. *Apparent buttresses ;* 4. *Pillar-clustering*, with reference to the ribs, each rib (whether of the vaulting or of the arches) being given to a particular shaft ; 5. *Pinnacle-clustering ;* 6. *Window tracery*, with subordination (of principal and minor tracery bars) ; and, lastly, *Foliation*, or *foiling*, an universal though seemingly non-essential ornament. These seven peculiarities may be considered necessary to constitute the complete Gothic ; but some very beautiful styles arose before this complete development, by the carrying out of *some* of these principles alone ; and wherever *any one* of them (especially pointed arching) is consistently observed, a beauty is derived from this consistency. All the styles which completely carry out this principle come under the general term *Early Pointed*, and are further distinguished as *Early English*, *Early French*, &c. ; the word 'Pointed' being understood. Of all these, the Early English may be esteemed as decidedly the most

Temple church offers a rude approach, viz., a dodecagon with its covering supported by six pillars and eighteen arches, all of equal span, dividing the whole into a central hexagon. surrounded by six square and six triangular compartments, all equilateral, and making the thirty lines composing the plan all equal. The preceding example of hexagonal planning approaches the same idea. It represents the two stories of the royal mausoleum at St. Denys, destroyed in the first French revolution.

TEMPLE OF THE WINDS

page 273

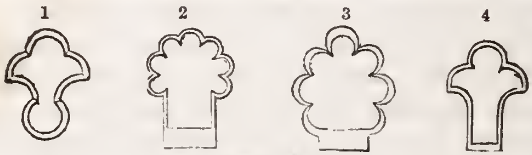
pure and consistent. It is not confined to England, but nearly so; its only continental localities being Brittany and the western part of Normandy. All provinces further east exhibit various kinds of Early Pointed, different from ours; and some of which were formerly supposed to display a more advanced stage, or a nearer approach to the complete Gothic, than the contemporary English examples. Thus Amiens cathedral, begun in the same year with Salisbury, certainly at first sight appears, with its large four-light windows and varied tracery, much more Gothic than Salisbury, where there is no tracery, or only the first rudimentary effort towards it. But on a closer inspection, we find that much of the Amiens tracery (as the lower nave windows and the great end rose windows) consists of after-additions: that the original windows show no greater advance than some at Salisbury (those of the chapter-house); that the remaining tracery being simply composed of foiled circles or foil-circles* packed together, is no more than what the Salisbury builders may be supposed quite capable of designing, had they possessed the desire, or the funds, for such enrichment; and, lastly, that if the *tracery* is more complete at Amiens, other features (as the vaulting) are precisely similar in both, while others are decidedly more advanced in England. This is specially the case with the arch-mouldings and pillars, which, even in older buildings than Salisbury, exhibit a richness of clustering far beyond those of Amiens, whose groups of five only, with Corinthian capitals and square plinths and abaci, hardly indicate any advance from the Romanesque.

It is easy to conceive that the Gothic features might have appeared one by one in a different order in different countries, and that while one nation made its first advances by

* The nomenclature of Rickman seems on this point more concise and every way preferable to that of Professor Willis, whose *foiled* arch and *foliated* arch correspond respectively to Rickman's *foil* arch and *foiled* arch, which, to any observer of Gothic buildings, seem hardly to require explanation, the former being where the whole archivolt is broken into several curves, and the latter where these are only inserted within a simple curve.

means of the pointed arch and vault, another invented tracery or foiling, a third began with the acute spire and pinnacle, a fourth pushed forward the subdividing of the cluster-column and many-shafted jamb. This last was the case with England, where many round-arched examples even are so Gothic in this respect that they present as many vertical lines as any building: Winchester tower, of the eleventh century is an example.

Germany boasts of the first examples of the Gothic arch, and yet, strangely enough, was the very last country to abandon the round arch, which continued to struggle with the pointed forms, and render the "Early German," even down to the middle of the thirteenth century, an incongruous mixture, unworthy the name of a style. In buildings with complete pointed vaulting, and all the beautiful varieties of plan and outline mentioned above, when we turn to the windows, those favorite types for recognizing the Gothic styles, instead of the beautiful grouped lancets of the Early English, we meet with such forms these:



Early German Windows.

The foiled forms were probably introduced from the East, (being common in Arabic architecture,) and though the Germans were perhaps the first to use these forms extensively, it was long ere they learned their true use, not to be placed alone, but as adjuncts to graver and more simple forms. The round trefoil arch seems in Germany to have preceded the common pointed one, and in grouping two or more openings under one arch, they aimed at variety rather than unity in their forms. Thus, using the letters T, R, P, and *, to express pointless *Trefoil*, *Round* arch, *Pointed* arch, and foiled circle, we find such combinations as these:

R	R	R	R	T	T	T	P	P	P
T T	T	P	P P	R R	P P	R	T	R	*
	T T	P P	*pp pp*			R R	T T	R R	T T

But not till later than in France or England do we find—

P	P		P
P	*	and	P P
P P	P P		*pp pp*

When, indeed, the Germans did adopt these combinations, tracery of the most beautiful kind rapidly followed, and in St. Catherine, at Oppenheim, and the glorious design for Cologne (1248), this part at least of the Gothic system certainly attained its fullest development, rather sooner in Germany than elsewhere. So rapid was this development, that there is hardly an example in that country of *Early Pointed* (St. Elizabeth, at Marburg, is the chief); for no sooner did their architecture become completely pointed than it became complete Gothic.

The German Gothicists particularly excelled in the design of spires and the grouping of pinnacles, which they carried to a complexity unknown elsewhere. This feature sprung from the simple practice of finishing a square turret with an octagonal or conical spire, and then occupying the spandrils left on the plan, by four smaller spires ; a proceeding as old as the tombs of the Etruscans.

The practice of window tracery everywhere had its origin in window-*grouping*, placing two or three lancet windows beside each other, and one or more foil or rosette windows above and between their heads, in order to fill out the arched cell of the vaulting, which then necessarily gave the whole group an arched outline ; and this was indicated externally by a general drip-mould or label. It then became desirable to lighten the irregular masses left between the perforations, and this was done by piercing these masses, or spandrils, and reducing the solid frame of each foil or rosette to an equal thickness all round, as if several such frames or rings were

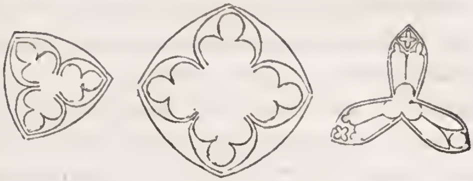
packed into one great arched opening, which henceforth was regarded as *one* window instead of several.

Each country has had its successive styles of tracery, and each has begun with the simple subdivision of one arch into two, and these sometimes into two again, filling up the space between the heads with a *circle*, as at Marburg ; a *foiled circle*, as at Salisbury chapter-house, and the aisles of Cologne; or finally a *foil-circle*, as at Westminster, and the clerestory of Cologne, where it is subfoiled :* thence proceeding to pack together such forms over an *odd* number of lights, to which the method of continual bisection would not apply ; and thus the first kind, which may be called *packed* tracery, became complete. Deviations from the principle of packing led to the general tracery, absurdly called "*geometrical ;*" for all Gothic tracery is geometrical, none is hand-drawn. This beautiful, purely *unmeaning* tracery was succeeded in all countries by the flowing loop or leaf, and then by the peculiar national After-Gothic. Germany, however, as it had been the first to perfect, was also the last to abandon the "geometrical" tracery, which continued there, even into the fifteenth century, our Perpendicular Period. England and France, however, in the fourteenth century, abandoned the unmeaning for the flowing leaf-tracery ; and this, notwithstanding its beauty, had hardly time to show itself before it was superseded, here by the perpendicular, and in France by the flamboyant. Hence it happens that of the three great classes of tracery,—"geometrical," flowing, and perpendicular,—while the last is, as every one knows, by far the commonest in England, the most abundant kind in France is flowing (flamboyant), and in Germany geometrical, *i. e.*, unmeaning.

The unmeaning tracery of Germany is very beautiful, and

* *Subfoiling* seems a more concise and clear term than *bifoliation*,—employed by Willis,—which is liable to be mistaken for the practice, common in France, of dividing a flame-like form into only two foils.

generally partakes of the packed character, the following forms occurring very abundantly. The



Elements of German Tracery.

convex-sided triangle and square are placed in all positions indifferently, and the frameless trefoils and quatrefoils are often formed on the basis of these figures instead of the circle. The foilings and subfoilings, formed by a very narrow but deep chamfered member, leave their little spandrils, (called *eyes* by our workmen,) entirely open, producing the lightness almost of metal-work. Circular windows,—in England almost confined to the ends of the transept,—were employed abroad wherever a window of the ordinary form would have become of too low and broad a proportion.*

* The term *marigold* has been applied to those circular windows in which radiating mullions prevail, and *rose* to those in which no such lines are found. The preference given to the latter may be traced to the feeling for subordination of the classes of form. A general form of the third class should not be filled up with details of the second.

The finest rose windows, perhaps, are at St. Ouen, (Rouen.) and the immense ones at Beauvais, in which however, there is not enough subordination of different classes of mullions. The finest of the radiating sort are at Strasburg, Westminster, and the south front of Amiens, where a pleasing variety is produced by the lines radiating from points a little distant from the centre, so

as to give alternately a few radiating and a few parallel mullions. The figure *a*, called *pentalpha*, is very common in French circular window tracery ; and they followed the example of flowers in founding their division, chiefly on the numbers 3 and 5. those divisible by 4 being comparatively rare. The term *wheel*, applied indiscriminately to all round windows, would be better restricted to those called in France *roses tournantes*, which differ from ordinary roses in having the similar sectors of the pattern not alternately reversed, but all turned the same way, which gives the idea of rotation. There are many varieties of them, though none contain more than six or eight panels, there being none above the smallest scale, probably from a feeling of the instability given by their rotatory expression. Hence the use of a large and complex one, as a principal and central feature, in a church lately finished at Islington, must be considered in very questionable taste.

When the Gothic system had attained its culmination, the chief differences were that *vault tracery*, *pillar-clustering*, (and perhaps we may add, *moulding*,) were best developed in England ; *spire design* and *pinnacle-clustering* in Germany ; *window tracery* in France ; and *foliation* in the Netherlands and Spain, (where it took an extraordinary richness and complexity from the Arabs, its probable inventors.) All these, however, were rather differences of degree than of kind, and the style might be said to be now every where the same.

The Gothic, then, had in the fourteenth century become a complete system, as consistent in its principles as the architecture of the ancient Greeks, to which it was yet in many respects directly opposite ; and it is truly surprising to trace how by a continued steady progress in one constant direction, an originally perfect style was, through various stages of decline and even deepest barbarism, gradually converted, after almost twenty centuries, into another style as perfect as the first, yet opposite in many of its principles.

This opposition appears stronger, the more perfect are the two varieties of Greek and Gothic which we compare. The better each may be of its kind, the more perfect is the contrast, and the chief points of contrast are the following :

In the pure Greek, an arch was inadmissible ; in the pure Gothic, a lintel or beam is equally inadmissible. In imitative Greek, all arches have to be disguised as beams ; in imitative Gothic, all beams had to be disguised as arches.

In the former, the props required to confine the arches must be concealed or disguised ; in the latter, props must appear, whether they are wanted or not.

The severe unity of the Greek will not admit of scenery, *i. e.*, decoration behind decoration. The wall behind a colonnade was plain, not even windows being admissible there. The Romans advanced a step from this, allowing two systems of decoration together, the front system of columns and entablature, the hinder of arches or windows. The Romanesque builders carried this further, and in their latest

works placed arches behind arches in three or more depths. This was approaching the Gothic, in which style (and in which alone) the planes of decoration are unlimited as to number.

Lastly, looking at the general character, the expression of the Greek temple is that of majestic *repose;* that of the Gothic is aspiring *flight*, or at least *growth.* The first arises from the absence or non-perception of oblique pressures. Everything gravitates straight downwards, and its weight seems somehow to be rendered peculiarly visible. But the Gothic arches and gables, the tapering buttresses, the sprouting crockets and bud-like finials, the bristling pinnacles and spires, all seem shooting upwards, and by their terminating all at different heights, seem aiming higher and higher; while internally the same character is preserved by arch above arch and canopy above canopy, by the palm-like combination of shaft and vaulting ribs, and lastly, by the great preponderance of vertical lines over horizontal ones, both in number and (perspective) length.

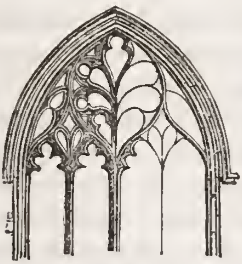
This last circumstance has, from its simplicity, been too exclusively dwelt upon, and even regarded by some as *the* Gothic principle, a distinction which it does not merit, for the aspiring character cannot be imparted by this alone; and on the other hand, this character is possessed in the highest perfection by many buildings which have (in the exterior at least) more numerous and extensive horizontal lines than vertical ones (as is the case with Salisbury), nor do the *nearly* vertical bear a greater proportion to the horizontal than in Grecian buildings, in which, owing to the diminution of the columns, &c., hardly any *truly* vertical lines occur.

Rickman, however, made the important observation, that in the complete Gothic, *every* horizontal line meeting a vertical one, either terminates or changes its direction, while the vertical continues its course unaltered. In the pure Greek precisely the reverse takes place; *all* vertical lines are stoped by the first horizontal one they meet, while the horizontal continue (generally without a bend) from corner to corner

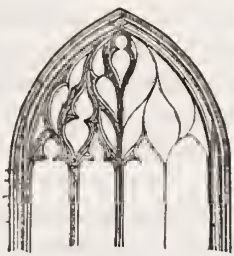
of the building. The difference, therefore, consists not so much in the number or extent of horizontal lines, as in the fact of their being *unbroken* in the Greek, and *frequently broken* in the Gothic. In both they are equally necessary to preserve the unity of the building, by tying all its parts together. The neglect of this, arising from the misapprehension and abuse of the "vertical principle," as it is called, has led in modern times to the erection of churches so totally destitute of unity, as to resemble a group of chapels of various heights stuck together. That this is not Gothic will appear by examining those Gothic structures (few indeed in number) which have been finished in one lifetime, or after one design, and escaped the unscrupulous alterations by which so many grand edifices have been reduced to patchwork. Such buildings are the cathedrals of Salisbury, Rheims, Milan, Cologne, St. Ouen at Rouen, and the celebrated chapels at Cambridge, Windsor, and Westminster. These include all the style, and the utmost degrees of verticality, yet all possess perfectly that unity which arises from correspondence of horizontal divisions and features all round the building, and is as necessary in this style as in any other, to distinguish a great building from a group of little ones.

But the aspiring principle was liable to abuse by its inventors in the palmy days of Gothic art, as well as by their imitators now, though in a different manner. No sooner was this beautiful tendency of the style observed, than it seems to have become the main object of Gothic design to increase and push to the utmost this expression so appropriate to a religious edifice. It was a fine idea to make *everything* in God's house point heavenward ; but to the various methods resorted to in different countries for exaggerating this expression, we must partly refer the gradual decline and fall of this wonderful style, which proceeded by different steps in each country, giving rise to what Professor Willis has happily named the different forms of *After-Gothic*. The Germans seized on the idea of *growth*, and the buding and sprouting

expression ; but perhaps the French were most successful in increasing the aspiring expression : by a slight change in the prevailing forms of the flowing tracery, they converted the loops or leaves into flame-like forms, till the Flamboyant buildings, appeared not vegetating, as in Germany, but *blazing* from the foundation to the bristling finials. The difference between this style of tracery and our own flowing style (exemplified in the west window at York), is, that while the upper ends of our loops or leaves are round or simply pointed, *i. e.*, with *finite angles*, the upper ends in France terminate, like the lower, in *angles of contact* (those formed by two curves that have a common tangent). It was necessary to the leafy effect that the *lower* angles should be



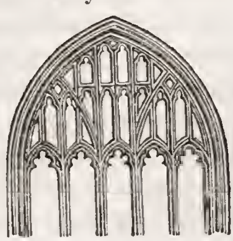
English leaf-tracery



French flamboyant tracery.

tangential ; but to the flame-like effect, that the *upper* ones should be so, even if the lower were finite ; and hence some examples of flamboyant tracery, turned upside down, form a kind of leaf-tracery.

Our countrymen, however, adopted a method which was less conducive to the aspiring expression, and which conducted them to a style less rich and certainly less varied than any of the other After-Gothics. Erroneously supposing that an abundance of vertical lines would increase this character, they were led to convert all the flowing lines of the window tracery into vertical ones, to omit the capitals of nearly all the smaller shafts



or shaftlets, thus converting what had been blank arcades into mere panels, and then to multiply, diminish, and extend these panels and endless repetition of vertical lines, over every part of the interior, and, in florid buildings, even of the exterior.

But the "Perpendicular Style" may also have arisen from that principle of *constructive unity*, on which we have so much insisted, and according to which a style is pure and perfect in proportion to the exclusiveness with which a certain mode of construction pervades, or appears to pervade, every feature, from the greatest to the least. In Gothic architecture this mode of construction is *arching*, in other words the subjecting materials to compression alone, never to tension or to cross-strain. Hence the perfection of this style requires that no member, however short or strong, should be treated, or appear to be treated, as a *beam*. All materials must appear (as far as the eye can judge) to be not only in equilibrium, but in such equilibrium as would apply to *flexible* as well as rigid bodies. Hence the apparent flexibility which every one notices in fine Gothic architecture; the stone is treated as though it were flexible, *i. e.*, no dependence is placed on its rigidity, and therefore it appears to have none. Now, in applying this to the chief kinds of tracery, we must remember that the statical conditions of a flexible Gothic arch require a weight concentrated on its vertex, but will not admit of any *concentration* of weight on any other point. But in the "Geometrical" tracery, the arches over the lights receive generally no pressures on their points, but concentrated pressures on certain parts of their haunches, viz., where they touch the circles or rosettes that seem packed into the window-head. Such tracery, formed of a flexible substance, could not keep its form. The flowing loop-tracery is an improvement on this, and the flamboyant still more so; but in the Perpendicular Style alone do we find a complete recognition of the principle that the Gothic arch should be loaded only on its vertex. In this style alone do we find

tracery which, if converted into a flexible material, would undergo no change of form.

That the perpendicular tracery was used from this feeling rather than from false taste, will appear from that great type of perpendicularity, Henry the Seventh's chapel, in which, though the principle thoroughly pervades every other part, it is not to be traced in the flying buttresses ; for here statical principles rather required the voiding to be effected by *circles* (as in the spandrils of the Pont-y-Prydd and iron bridges), and accordingly this is done. How different is the constructive consistency here shown, from the want of it in certain earlier French works, the cathedral of Orleans, for instance, where the window-heads are packed with rings and rosettes, while the flying buttresses are pierced with perpendicular archlets, concentrating all their weight on certain *points* of the lower curve, against all statical propriety.

But the grand error of the "Perpendicular" was its introduction of a graver class of form in details than prevailed in main features.

Another fault peculiar to the decline of the system in England sprung from the reduction of *paneling* (originally an excellent constructive principle, for the economy of material,) to a source of ornament merely. Common sense tells us that a panel is a method of diminishing bulk or weight without diminishing superficial extent, and is therefore only applicable to parts whose office depends on their *extent*—whose duty is to enclose or fill up spaces ; but never to those which have to support. Thus the spandrils of a bridge are proper places for paneling, but never its *piers*. The application of paneling, however, to supports was left to the very latest examples of Gothic degradation ; but for a long time previously, the principle was abused in the fan-tracery vaulting, whose ribbing and paneling was not constructive, but only decorative ; the joints occuring indiscriminately in the centre of a panel, or the centre of a rib.

Other abuses overran the style in different countries,

many (but not all) of which may be referred to the change admirably described by Ruskin, as occuring everywhere at the culmination of the style, viz., the *the transference of attention from the masses* (of light or shade) *to the lines.*

In Germany the chief vice was *interpenetration*, or the making mouldings appear to pass through each other, instead of stopping each other.* This was at length carried to such extent, that no member could stop against another, but must seem to run through and come out on the other side, even though it were in consequence obliged to be cut off abruptly in the air, giving rise to *crossed foiling*, and what has been called *stump*-tracery. Moreover, that originally beautiful and useful member, the ogive crocketed hood, became to the German designers, what the panel was to the English. It overgrew everything else, till the buildings became covered with tracery, not of panels but of intersecting hoods, which, not confined to their three purely Gothic forms, the rectilinear, the concave-sided, and the reflexed or ogive, now ran into all imaginable shapes, which, interpenetrating in all directions, gave the idea of entwined plants, an effect increased by the innumerable crockets.

In France, the Gothic, in its flamboyant form, seems to have maintained a certain degree of purity longer than any where else, for the transept-fronts of Beauvais, built in 1555, exhibit hardly any instances of Italianizing tendency. Strongly marked horizontal cornices, however, begin to stop the vertical lines, and the latest French buildings free from Italian details, display a style called *Burgundian*, with the same general tendencies as the English *Tudor*, but far less skilfully carried out; the arches being not only depressed but *pointless.*

Everywhere the finishing stroke was given to expiring Gothicity by the return to beam and lintel construction, and

---

* Perhaps this arose from a fancy to repeat and exhibit everywhere the symbol of the *cross*. It is known that some monkish writers of that age amused themselves with finding crosses in every object of nature.

the attempts to disguise these straight horizontal forms into the semblance of depressed arches. The loss of *constructive unity*, the return to universally *mixed* construction, (as in the Ante-Gothic ages,) completed the downfall of this, as it had before completed the downfall of the antique system.

In one respect, however, the fall of the Gothic architecture perhaps differed from that of the Classic, and was more complete. It was a fall out of which nothing could be expected to arise,—a fall not of a style or system merely, but in a certain sense, of the entire art. It was the end of a progress in one constant direction, which had run through the whole history of European architecture, quite independently of the changes from style to style—unaffected by the Romanesque debasement of the art or its Gothic renovation. This was the progress from *magnitude* to *multitude*. Though twice attaining constructive and decorative *truth*, it is obvious that the apparatus of the art, in its second complete phase, consisted of diminished and multiplied derivatives from the chief structural members of its first phase. The process could be carried no further: complication had reached its limit,—in the finite divisibility of the material,—in the finite capacity of man,—and the finishers of those piles should have inscribed on them, "*Architecture is finished; henceforth be content to copy.*"

The Gothic system fell by its own inherent principles of decay, and left the field vacant before the perceived absence of true architecture rendered the importation of a new system necessary. Imitations of the grotesque must be carefully guarded against being classed with the pure Gothic.

Post-Gothic Architecture.—Coeval with the last great transition of human society: from the invention of printing dates the fall of Gothic art.

The present Florentine is the Doric style of modern palatial or domestic architecture.

Venice, the luxurious mistress of the Adriatic, like its pro-

type the *Corinthian* of old, has superseded its rivals, having been till within the last few years the general model to the architecture of all trans-alpine Europe. Its aim was splendor, variety, luxury and ornament. Intermediate between these two schools arose the modern Roman.

The English school was founded on the Venetian.

In Florence, mere eye-pleasure is foregone, variety denied, monotony endured for the sake of grandeur, and the higher objects of the art.

In Venice, the higher excellences are sacrificed to the lower; true grandeur, to pompous effect; intellectual sense of fitness, to mere eumorphic beauty; the mind, to the eye; self-concealing art, to self-displaying art.

To describe the schools more technically, or with regard to *rules* rather than principles,—the Florentine is mostly astylar, the style of fenestration and rustic groins; the Roman the style of pilasters; the Venetian, that of columns.

CONCLUDING REMARKS.

Among the few, then, that enlist on the side of Truth, and resolutely engage in this perpetual conflict against false, against popular, against national taste, it must ever be borne in mind, first, that *there is no substitute for thought.* All the ponderous tomes of examples, specimens, &c., from Adams and Stuart downwards, have been intended, or received, for this purpose; and, *as such*, are not only totally worthless, but extremely prejudicial; though invaluable as materials for analysis, free criticism, and search into principles,—for which purposes they have never yet been used.

Nothing can increase the value of a design, which does not increase the labor of the designer, (by designer I do not mean draughtsman.) *Every reference to precedent should do this, and will do so with every true artist.* But the false artist refers to precedent, to save himself trouble; that is, to cheat his employers, by diminishing the value of his work, without diminishing its apparent value.

II. Novelty-hunting, and the false use of precedent, are the Scylla and Charybdis between which, the many, and the architects of the many, are forever destined to be wrecked. It is possible, however, to fall into both at once.

That nothing is beautiful which is without motive, most of the thinking will admit; yet it is necessary to add, that *novelty* and *antiquity* are no admissible motives. But though age affords no reason whatever for the *adoption* of any thing, it gives every reason for its *examination* and *study.*

III. We cannot too strongly instil into the reader, that while *novelty* is in itself neither a beauty nor a fault, but totally immaterial,—*novelty sought for its own sake* is the destruction of art. The end of art is truth. The instant it proposes any other aim, (be it *novelty,* or to "catch the

spirit" of a particular time or place, *i. e., mimicry,* or any other fancy,) it ceases to be art ; and what is not art, is not architecture. Aim at catching the spirit of *all* true architecture, not that of any one style,—still less, of a notoriously *false* style.

IV. If, as we have also endeavored to instil, the main distinction between artists is, that some strive to put as much thought as possible into a given work, and others to do that work with as little thought as possible,—then, if one of these principles be art, it follows that the other is not merely its absence, but its opposite ,—not a mere negation, but an active principle, for which, finding no name used, I would propose the term *anti-art.**

A very small portion of *anti-art* peeping out, is enough to destroy all our pleasure in a work of art. Witness the pots and cowls that finish the sky-line of most of our piles of architecture. A foreigner would think this nation bankrupt, to judge by the innumerable public buildings standing unfinished, covered with these hideous make-shifts.

V. The highest beauty is fitness. Therefore, when you see a thing highly beautiful, *beware of copying it* till after mature study ; for the more beautiful (*i. e.,* the fitter) it may be in its situation, the less likely to be fit (*i. e.,* beautiful) in any other.

Those who wonder why architects often condemn what other persons of good taste admire, seem to forget that the latter cannot distinguish what belongs to the designer, from what belongs to the theory of his art as he found it, and

---

* Here is the simplest instance I can find, which will display the two principles. The reader knows the old established way of cutting the stones of an arch in rusticated masonry, each stone presenting a five-sided face: well, two other modes have lately been adopted, each making the faces of the stones four-sided. In one, the voussoirs are alternately long and short, like battlements ; in the other, their extrados is cut to a regular curve. Persons of taste, however, prefer the old method, but without knowing why. Now I will tell you why. Just sketch the three on paper, and you will perceive that the old is by far the most troublesome to design, yet gives the least work to the mason; having fewest oblique joints. Thought is expended to save manual labor. But in both the new modes, mental labor is saved at the expense of the manual. The first is *art,* the others *anti-art.*

which not only the true artist learns, but even the most ignorant *falls into*, as we inevitably fall into the habits of those around us. But the eye of an architect has acquired the power of instantly separating these two parts of the design, setting aside the one as a mere matter of routine, but singling out and fixing itself on whatever is the *designer's own.* Now, if we perceive that all the beauty,—all the truth in the building, belongs to the former portion ; that whatever belongs to the designer, whatever is new,—is false, —is adopted either for novelty, or to save thought, or for affectation, or for anti-art, we condemn the work, and justly : for what avails it to have been correct as far as rules and precedent would apply, if *wherever* he has acted for himself he has sinned ? What avails it to have repeated truly the 990 words for which he could find authority, if the 10 which he was obliged to add are *all* false ? It is these ten *alone* that show whether he is an artist or not ; and these things, though small, and escaping the casual glance of the public, glare to our eyes as huge blots, totally defacing the routine beauty ; though that may form the major portion of the work, and may cause the uninformed to regard it as *pleasing on the whole.*

Beware of mistaking this *on the whole*, for *as a whole.* Sir Joshua Reynolds observes, that "the totally ignorant beholder, like the ignorant artist, cannot comprehend a whole, nor even what it means." When such speak of the effect *as a whole*, they mean *on the whole.* The effect to them is pleasing, if it contain a majority of pleasing parts.

Such are now the most influential judges of art. By a singular inconsistency, those who constantly profess to be *no judges*, are really the style-formers. They say, "We know nothing of the art, but we know what pleases us." But what does this assume ? Plainly, that the art is intended to *please them.* This is the grand art-destroying error. No true art is, or ever was, meant to please the many, but to teach them when to be pleased.

In limiting, we fear, the number of true artists, it must be remembered that one may be a true artist without being a master, or any thing like one. The difference is this: most buildings are so transparent, that we look at their front, and see through to the back of the designer's mind. According to the proportions we see of *thought-spending* or *thought-saving* spirit, so we admire or condemn ; and when we can discern no self-sparing, no anti-art, we pronounce the work *purely elegant ;* but not necessarily *masterly.* The work of a master is equally or even more transparent ; but though the eye pierce deeper, and perhaps find more faults, it cannot reach the bottom. Admire as much as we may, we perceive that there is more beyond, left unadmired.

The few principles which we have endeavored to elicit or explain in this volume, have been arranged in an upward progression, from narrow and particular, to wider and more general ones. We first tried to distinguish the different grades of beauty in building, and assign them their true relative ranks. Thus color, whose laws of harmony are purely physical, came before uniformity, which appears sometimes addressed to the sense, and sometimes to the mind. Beauty of outline, being wholly addressed to the mind, though perhaps to its lowest faculties, came next, and was traced to the union of unity and variety, which union is to be effected in two ways,—by gradation, and by contrast. Proceeding, then, from unmeaning beauty to that which is distinguishable into classes, we showed that its two opposite characters—*grandeur* and *elegance*—depended on the comparative prevalence of these two principles—contrast and gradation. According to the relative proportions of these, we divided all possible forms into five classes, and insisted on the observance of the natural disposition and subordination of these classes one to another, as practised in all the pure and admired styles. This we regard as the most important principle in mere *geometric design,* apart from constructive and other fitness.

We then considered the two cognate qualities of *sublimity* and *picturesqueness*, referring the former chiefly to, 1. The prevalence of contrast, and rarity or absence of gradation; 2. The expression of mechanical power in the construction; 3. The principle by painters called *breadth*, *i. e.*, the collection of every thing or quality into great unbroken accumulations; 4. A quality we called *depth*, the reverse of flatness or shallowness. On the difficult subject of picturesqueness, we simply gave the notions of Ruskin, that it arises from the same qualities that would be sublime in the subject itself, attaching themselves not to its essence, but to some *accident*, as light and shade, color, situation, state of decay, &c.

We next considered how nature should be imitated, with generalization, *i. e.*, by taking all possible objects that have the character we want to give, extracting all that they have in common, and rejecting what is peculiar to each. We insisted on the same method as necessary in the imitation of masters, styles, and manners; and endeavored to distinguish between true and false imitation, or copyism. Another kind of false imitation, viz., *deception*, was then considered; the grievous error of regarding it as an object of art, the total destruction thereby fallen on popular art, and the great caution necessary for the thoughtful, who would escape this defilement. Connected with this, we endeavor to enforce *constructive truth*, or the non-disguise of the real statical principles of the construction; and lastly (a principle hitherto totally neglected by the moderns,) *constructive unity*, or the consistent adherence to *one* statical method throughout a building.

The two short reviews of the "pure styles" afford the reader particular instances and modifications of these principles, and perhaps of some higher ones.

Pure architecture, then, may be regarded as consisting in the combination of constructive and decorative TRUTH, in their widest sense, or of constructive and decorative UNITY.

This union was anciently sought by all nations,—attained

by the Greeks alone,—dissolved by the Roman introduction of the arch,—gradually lost by the increasing admixture of that constructive principle,—RESTORED by its total adoption, to the exclusion of all other apparent construction,—and a second time lost by the increase of tensile construction and the indiscriminate mixture of all constructive methods.

Since this second degradation of the art, however, many great artists have lived, especially in Italy, a country which has never attained a system of constructive unity. For, except the pseudo-Greek buildings of the empire, and the pseudo-Gothic pile of Milan cathedral, with a few other exotic importations, it has never seen a building possessing even the appearance of constructive unity. Such a country is that in which we might look for the development of a style suitable to the *mixed* construction practised for the last three centuries; and, accordingly, in that country, such a style did, after many ages of unsuccessful efforts, at length appear, under the constellation of artists that adorned the fifteenth and sixteenth centuries. The system then developed was a *new* one, though composed of classic details. It affords more scope for variety in general arrangement than either of the pure systems,—certainly more than any impure ones; and it possesses a pliancy that may be bent to all the purposes probably that can ever be required in buildings of mixed construction. As long as such construction prevails, we may safely predict the continued prevalence of this architecture among the thinking.

But the two pure systems, perhaps it will be said, are things too good ever to be entirely given up. If so, far more are they too good to be abused and caricatured. If they are worth copying at all, they are worth copying completely; and this can never be done but by copying their *construction* as well as their decoration. If modern habits or means will not permit this, they will not permit the old style. Count the cost, therefore. If you want to imitate the archless style, your building must be archless, or a huge lie. If you

imitate the beamless style, it must be beamless; and every unvaulted building, ancient or modern, that apes this style, is a motiveless and unmeaning sham.

Not less preposterous than the attempt to revive *dead styles*, is the requirement to invent, for ordinary buildings, a *new* one. As long as we have no new style in construction, we *can* have none in architecture; but if we call the mixed construction a new kind, we *have* a new style adapted to it, —a modern, a living style; the growth of modern circumstances and of the existing modes of construction:—*new*, moreover, inasmuch as we are only on the threshold of its possible combinations and varieties, far more inexhaustible than those of either of the pure systems. In this country particularly, the beauties of the modern architecture are hardly known, nor can it be said to have ever had a fair trial, or indeed any trial in more than one or two classes of buildings.* It would be ridiculous self-conceit in an architect, to pretend wilfully to go back and try to solve anew that which has been already solved, and only by the succession of a long line of great artists. He can never hope to overtake them with such a start in their favor; while by commencing from the point they reached, the poorest talents may advance beyond them.

But while no inventive architect would *wish* for a new style, convinced that there is far more scope for variety and new combination in one already enriched with the accumulated genius of three centuries; it is certain that, in another point of view, a new style is indispensable. There *is* a class of buildings tending towards a new style of construction,—becoming less mixed in this respect,—and approaching a consistent use of *tensile* covering to the exclusion of every other.

* What are called classic churches, for instance, are, for the most part, mere anti-art, no more Classic than they are Chinese. Wren had no opportunity of erecting a handsome parish church. His pupils fell either into littleness or Borominian corruption; and since their time, there have only been hole-in-the-wall preaching rooms,—sham temples,—and now pseudo-Gothicesque barns, copies of copies by mediæval village masons. England does not possess a modern church in the modern style.

To this third system of constructive unity, there is NO old style adapted. None was invented for it. It is a new thing, and its treatment must be NEW,—new, because subject to old principles; and to be effected only by a patient search into those old principles. Let us not mistake what we have to do. It is that which has been done only twice before; in the time of Dorus, and in the thirteenth century. We must carefully attend to the modes by which it was effected on both those occasions. On the first it was done most perfectly. There was the least to do. There was no lumber of a rotten system to sweep away. There was falsehood indeed to rectify, but it was only decorative, not constructive, and probably unbacked by prejudices and precedent. The second purification was less complete, but more like, in circumstances, to that now required. Its grand impediments were prejudices in favor of old but useless forms, and against an useful member (the buttress,), under the notion that it was unarchitectural. So is it now. The method of tying buildings together, (said Wren,) instead of giving the arches, &c., sufficient butment, is contrary to the principles of sound architecture. Yes, contrary to the only two systems of architecture known to him or to us, but not therefore contrary to all possible systems. A Greek would have condemned thus the method of wedging stones together by lateral pressure; and after this method was introduced and used in all buildings, it was fifteen centuries before architects could be brought to admit the appearance of this lateral pressure. For a still longer period has *tension* been a principle of building, and yet not of architecture; much longer has the *tie* been struggling for admission, and been refused. As nothing was effected towards the development of the second system till the arch covering became universal,—till a building became *beamless;* so can no advance toward the third be expected till this constructive principle becomes universal, in the widest covering and in the narrowest,—till a building be erected both *without lintel* and *without butment*

If the retaining of useless entablatures after their office was superseded by the arch, was a falsehood and a hindrance necessary to be swept away before any progress could be effected,—have we not a perfect parallel in the retaining of useless buttresses after their duty has been superseded by the tie?

There is, among other art-destroying fallacies, a notion now prevalent, that architectural styles spring up of themselves, and that if we wait long enough, in process of time a new one may grow up, we know not how. A new railway is more likely to grow up. Decorative *manners, fashions*, are not to be confounded with a new style, still less with a new system, such as THE TWO, the only two, that possess constructive and decorative unity. Yet even a new fashion does not come unsought,—without search after *novelty*. Far less can an architectural system arise but by an earnest and rightly directed search after TRUTH. For five thousand years have all the nations beyond the radius of Greek influence sought a true system of beam architecture, and *never* found it. For fifteen centuries did Europeans use the arch, and seek a system of arch architecture, before they found it. For a much longer time have Arabs, Turks, Chinese, sought the same, and *never* attained it. For twenty centuries did the Italians practise mixed construction, and seek a system thereof, before they attained it. Let us not deceive ourselves: a style never grew of itself; it never will. It *must* be sought, and sought the right way. We may blunder on in a wrong path forever, and get no nearer the goal.

A new style requires the generalized imitation of nature and of *many* previous styles; and a new system requires, in addition to this (as Professor Whewell has remarked), the binding of all together by a new *principle of unity*, clearly understood, agreed upon, and kept constantly in view. Constructive statics affords three such principles,—the DEPRESSILE, the COMPRESSILE, and the TENSILE methods,—the *beam*—the *arch*—the *truss;* of which the two former have been made

the bases of past systems: the third is ours, to be used in the same manner.

Such I believe to be the problem Truth propounds to the architects of the present time; but its solution will be found utterly hopeless, as long as we indulge any hankering after *novelty for its own sake;* any mean disposition to follow instead of correcting *popular taste;* and above all, let none dare attempt it till we have engraved on our compasses a hacknied sentence, but one which I suspect to contain nearly the whole theory of art,—SEEK NOT TO SEEM WHAT YOU WOULD BE, BUT TO BE WHAT YOU WOULD SEEM.

MONUMENT OF LYSICRATES.

page 273

ANOTHER VIEW OF THE TEMPLE OF JUPITER OLYMPUS.

page 273

ANCIENT MONUMENTS OF GREECE.

Every one can understand the regret with which we behold the remains of ancient grandeur, and the capitals ot buried empires. This feeling, so profound in Jerusalem and Rome, is even more so in Athens,—

> "the eye of Greece, mother of arts
> And eloquence, native to famous wits,
> Or hospitable—"

a city never so large as New York, but whose inhabitants produced within the short space of two centuries, reckoning from the battle of Marathon, as Landor says, a larger number of exquisite models, in war, philosophy, patriotism, oratory, and poetry—in the semi-mechanical arts which accompany or follow them, sculpture and painting—and in the first of the mechanical, *architecture*, than the remainder of Europe in six thousand years.

The monuments of antiquity which still exist in Athens have been described by Chandler, Clarke, Gell, Stuart, Dodwell, Leake, and other travellers, the most recent and competent of whom perhaps is Mr. Henry Cook, of London, author of *Illustrations of a Tour in the Ionian Islands, Greece, and Constantinople*, who has just made for the *Art-Journal* a series of drawings of those which are most important, representing them in their present condition. These drawings by Mr. Cook, we have partially reproduced in the present volume, making liberal use at the same time of his descriptions.

Until the sacrilegious hand of the late Lord Elgin despoiled Athens of "what Goth, and Turk, and Time had spared," the world could still see enough to render possible a just

impression of her old and chaste magnificence. It is painful to reflect within how comparatively short a period the chief injuries have been inflicted on such buildings as the Parthenon and the temple of Jupiter Olympus, and to remember how recent is the greater part of the rubbish by which these edifices have been choked up, mutilated, and concealed. Probably until within a very few centuries, time had been simply and alone the "beautifier of the dead," "adorner of the ruin," and, but for the vandalism of a few barbarians, we might have gazed on the remains of former greatness without an emotion except of admiration for the genius by which they were created. The salient feature (probably the only one) in the present rule at Athens is one which affords the highest satisfaction to those interested in this subject. Slowly, indeed, and with an absence of all energy, is going on the restoration of some, the disinterment of others, and the conservation of all the existing monuments; and time will probably ere long give us back, so far as is possible, all that the vandalism or recklessness of modern ages has obscured or destroyed. On the Acropolis the results of these efforts at restoration are chiefly visible; day by day the debris of ruined fortifications, of Turkish batteries, mosques, and magazines, are disappearing; every thing which is not Pentelic marble finds its way over the steep sides of the fortress, and in due time nothing will be left but the scattered fragments which really belonged to the ancient temples. "The details," says Mr. Cook, "of the partial destruction of this old fortress—founded 1556 years before the advent of the Saviour—under the fire of the Venetians, commanded by Morosini, are so well known, that I have thought it unnecessary to repeat them; but it is impossible to recall them without a shudder, as the reflection is forced on one, of what must have been their fate whose wickedness caused an explosion which could scatter, as a horse's hoof may the sands of the sea-shore, the giant masses which for ever bear witness to the power of that mighty agent we have evoked from the earth for our mutual destruc-

tion." At the west end of the Acropolis, by which alone it was accessible, stood the Propylæa, its gate as well as its defence. Through this gate the periodical processions of the Panathenaic jubilee were wont to move, and the marks of chariot wheels are still visible on the stone floor of its entrance. It was of the Doric order, and its right wing was supported by six fluted columns, each five feet in diameter, twenty-nine in height, and seven in their intercolumniation. "Here perhaps the chief work has been accomplished; all the now detached columns were built up with solid brickwork, batteries were erected on the spot occupied by the Temple of 'Victory without wings,' and on the square which answered to it on the opposite side of the flight of marble steps; the whole of which were deeply buried (not until they had severely suffered), beneath the ruins of the fortification which crumbled away under the Venetian guns. These walls have been removed, the batteries destroyed, and the material of which they were composed taken away; the steps exhumed, and the five grand entrances, by which the fortress was originally entered, opened, although not yet rendered passable. It would be, I imagine, impossible to conceive an approach more magnificent than this must have been. The whole is on such a superb scale, the design, in its union of simplicity and grandeur, is so perfect, the material so exquisite, and the view which one has from it of the Parthenon and the Erechtheum so beautiful, that no interest less intense than that which belongs to these temples would be sufficient to entice the stranger from its contemplation."

On the right wing of the Propylæa stood the temple of Victory, and on the left was a building decorated with paintings by the pencil of Polygnotus, of which Pausanias has left us an account. In a part of the wall still remaining there are fragments of excellent designs in basso-relievo, representing the combat of the Athenians with the Amazons; besides six columns, white as snow, and of the finest architec-

ture. Near the Propylæa stood the celebrated colossal statue of Minerva, executed by Phidias after the battle of Marathon, the height of which, including the pedestal, was sixty feet.

The chief glory of the Acropolis was the Parthenon, or temple of Minerva. It was a peripteral octostyle, of the Doric order, with seventeen columns on the sides, each six feet two inches in diameter at the base, and thirty-four feet in height, elevated on three steps. Its height, from the base of the pediments, was sixty-five feet, and the dimensions of the area two hundred and thirty-three feet, by one hundred and two. The eastern pediment was adorned with two groups of statues, one of which represented the birth of Minerva, the other the contest of Minerva with Neptune for the government of Athens. On the metopes was sculptured the battle of the Centaurs with the Lapithæ; and the frieze contained a representation of the Panathenaic festivals. Ictinus, Callicrates, and Carpion, were the architects of this temple; Phidias was the artist; and its entire cost has been estimated at seven million and a half of dollars. Of this building, eight columns of the eastern front and several of the lateral colonnades are still standing. Of the frontispiece, which represented the contest of Neptune and Minerva, nothing remains but the head of a sea-horse and the figures of two women without heads. The combat of the Centaurs and Lapithæ is in better preservation; but of the numerous statues with which this temple was enriched, that of Adrian alone remains. The Parthenon, however, dilapidated as it is, still retains an air of inexpressible grandeur and sublimity; and it forms at once the highest point in Athens, and the centre of the Acropolis.

To stand at the eastern wall of the Acropolis, and gaze on the Parthenon, robed in the rich colors by which time has added an almost voluptuous beauty to its perfect proportions —to behold between its columns the blue mountains of the Morea, and the bluer seas of Egina and Salamis, with acan-

thus-covered or ivy-wedded fragments of majestic friezes, and mighty capitals at your feet—the sky of Greece, flooded by the gorgeous hues of sunset, above your head—Mr. Cook describes as one of the highest enjoyments the world can offer to a man of taste. He is opposed to the projects of its restoration, and says that, "to real lovers of the picturesque, the Parthenon as it now stands—a ruin in every sense of the term, its walls destroyed, its columns shivered, its friezes scattered, its capitals half-buried by their own weight, but clear of all else—is, if not a grander, assuredly a more impressive object than when, in the palmiest days of Athenian glory, its marble, pure as the unfallen snow, first met the rays of the morning sun, and excited the reverential admiration of the assembled multitudes."

On the northeast side of the Parthenon stood the Erechtheum, a temple dedicated to the joint worship of Neptune and Minerva. There are considerable remains of this building, particularly those beautiful female figures called Caryatides, which support, instead of columns, three of the porticoes; besides three of the columns in the north hexastyle with the roof over these last columns. The rest of the roof of this graceful portico fell during the siege of Athens, in 1827. Lately much has been done in the way of excavation; the buried base of this tripartite temple has been cleared; the walls, which had been built to make it habitable, have been removed; the abducted Caryatid replaced by a modern copy, the gift of Lord Guildford, and the whole prepared for a projected restoration.

The Temple of Victory without wings, already mentioned, is, with the exception of the pavement, entirely a restoration; for nearly two centuries all trace of it was lost, all mention omitted. In removing one of the Turkish batteries, in order to clear the entrance to the Propylæa, some fragments were found which led to a more minute investigation; and, after a short time, the foundation, the pavement, and even the bases of some of the columns were disinterred, making its

reconstruction not only very easy, but extremely satisfactory. It is small, but of exquisite proportions, and now perfect, with the exception of a portion of the frieze, which is in the British Museum. A peculiarity of this temple is, that it stands at an angle slightly differing from that of the Propylæa itself,—a fact for which, as it clearly formed one of the chief ornaments to, and was certainly built after, this noble portico, it is difficult to assign any very good reason.

Such is an outline of the chief buildings of the Acropolis, which, in its best days, had four distinct characters; being at once the fortress, the sacred inclosure, the treasury, and the museum of art, of the Athenian nation. It was an entire offering to the deity, unrivalled in richness and splendor; it was the peerless gem of Greece, the glory and the pride of genius, the wonder and envy of the world.

Beneath the southern wall of the Acropolis, near its extremity, was situated the Athenian or Dionysiac theatre. Its seats, rising one above another, were cut out of the sloping rock. Of these, only the two highest rows are now visible, the rest being concealed by an accumulation of soil, the removal of which would probably bring to light the whole shell of the theatre. Plato affirms it was capable of containing thirty thousand persons. It contained statues of all the great tragic and comic poets, the most conspicuous of which were naturally those of Æschylus, Sophocles, and Euripides, among the former, and those of Aristophanes and Menander among the latter. On the southwest side of the Acropolis is the site of the Odeum, or musical theatre of Herodes Atticus, named by him the theatre of Regilla, in honor of his wife. On the northeast side of the Acropolis stood the Prytaneum, where citizens who had rendered services to the state were maintained at the public expense. Extending southwards from the site of the Prytaneum, ran the street to which Pausanias gave the name of Tripods, from its containing a number of small temples or edifices crowded with tripods, to commemorate the triumphs gained by the Choragi in the

theatre of Bacchus. Opposite to the west end of the Acropolis is the Areopagus, or hill of Mars, on the eastern extremity of which was situated the celebrated court of the Areopagus. This point is reached by means of sixteen stone steps cut in the rock, immediately above which is a bench of stone, forming three sides of a quadrangle, like a triclinium, generally supposed to have been the tribunal. The ruins of a small chapel consecrated to St. Dionysius the Areopagite, and commemorating his conversion by St. Paul, are here visible. About a quarter of a mile southwest from the centre of the Areopagus stands Pnyx, the place provided for the public assemblies at Athens in its palmy days. The steps by which the speaker mounted the rostrum, and a tier of three seats hewn in the solid rock for the audience, are still visible. This is perhaps the most interesting spot in Athens to the lovers of Grecian genius, being associated with the renown of Demosthenes, and the other famed Athenian orators,

> " whose resistless eloquence
> Wielded at will that fierce democratie,
> Shook the arsenal, and fulmined over Greece,
> To Macedon, and Artaxerxes' throne."

Descending the Acropolis, the eye is at once arrested by the magnificent remains of the temple of Jupiter Olympus, and by the Arch of Hadrian. Whether from its proximity to the gorgeous monument first named, or that it is intrinsically deficient in that species of merit which appeals directly to the senses, the Arch of Hadrian attracts comparatively little notice. It is, however, a highly interesting monument, bearing unmistakable marks of the decline of art; yet distinguished for much of that quality of beauty which gives so peculiar a character to the architecture of the Greeks. The inscriptions on the sides of the entablature have given rise to much learned discussion, and have led to a far more lucid arrangement of the city and its chief ornaments, than would

in all probability have been accomplished, had not inquiry and investigation been spurred on by the difficulty of comprehending their exact meaning.

Of two views of the temple of Jupiter Olympus, Mr. Cook chose that in which the Acropolis is seen in the distance. The three lofty Corinthian columns in the other engraving are diminished in the scale of the arch, while the Acropolis, from its greater complexity of parts, adds, perhaps, something of a quality in which the subject is rather wanting. "I am not sure," says Mr. Cook, "that the remains of the temple of Jupiter Olympus are not the most impressive which Athens offers to the eye and heart of the traveller, partly from their abstract grandeur—a grandeur derived from every element which could contribute to such an end—and partly from a position than which it would be impossible to conceive any thing more magnificent. The gigantic columns struck me with a sense of awe and bewilderment, almost oppressive; they consist, as may be seen by the engraving, of sixteen, the sole representatives of the one hundred and twenty which once formed this mightiest of Athenian temples. The least thoughtful person could scarcely avoid the question of where and how the remaining one hundred and four of these enormous masses can have vanished; and assisted by the fullest information which is to be acquired on the subject, it remains a matter of wonder to all. That time itself has had but little to answer for, the almost perfect preservation of portions is sufficient to prove; in some cases the flutings are as sharp and clean as when the hand of the sculptor left them, while, more generally, they bear disgraceful evidence of ill-usage of every kind, from that of the cannon ball to the petty mischief of wanton idleness. The proportion of these columns is quite perfect, and the mind is lost in charmed wonder, as wandering from part to part of the vast platform, it is presented at every step with combinations perpetually changing, yet always beautiful. So difficult do I find it to determine from what point of view these ruins are seen to the greatest

advantage, that I have appended two engravings, from which the reader may select that which best conveys to him the magnificence of the structure which has been thus slightly described." The temple of Jupiter Olympus was one of the first conceived, and the last executed of the sacred monuments of Athens. It was begun by Pisistratus, but not finished till the time of the Roman emperor Adrian, seven hundred years afterwards.

A proof of the varied character of the Athenian architectural genius may be found in the exquisite model, the lantern of Demosthenes, or, as it is more properly called, the Choragic monument of Lysicrates. It is, in common with the greater number of the remains of which we speak, of Pentelic marble. By whomever conceived, designed, or executed, this must have been a labor of love, and the result is such as might be anticipated from the consequent development of the highest powers of one to whom a people like the Athenians would entrust the task of doing honor to those who had paid to their native land a similar tribute. It is small, and formed of a few immense masses: the roof is one entire block; the temple or monument itself is circular, and is formed of six slabs of pure white marble, the joints of which are concealed by an equal number of beautiful Corinthian columns, partly imbedded into, and partly projecting from them. These have been fitted with such exactness, that before the "fretting hand of time and change" had done its work, the whole must have appeared as if cut from one solid mass. We have this single example of a class of buildiugs once so numerous that they formed an entire street; but however grateful one may feel to the hospice, which, being built over, protected it from the ruin of its companions, we can scarcely regret its disappearance, through which alone this exquisite result of intellect and refined taste may be seen as represented in the engraving.

The Temple or Tower of the Winds, has been very justly termed "the most curious existing monument of the practi

cal gnomonics of antiquity." In architecture no very elevated rank can be assigned to this edifice, nor is there, even in its ornamental portions, any very remarkable evidence of the higher order of Grecian art; the execution, indeed, can in nowise be considered equal to the conception, which, if somewhat fancifully elaborated, is at least highly to be esteemed, as uniting in a more than ordinary degree the practically useful with the poetical ideal. Near the new Agora, and consequently in the heart of the more densely populated division of the city, this indicator of the wind and hour must have been a valuable contribution to the Athenians, and must have given to its founder, Andronicus Cyrrestes, a proud position among the *bene merenti* of the moment. Its form is octagonal, the roof being of marble, so cut as to represent tiles; upon the upper portion of each face is sculptured the figure of one of the eight Winds; these floating in an almost horizontal position convey, either by their dress, the emblems which they bear, or the expression of their features, the character of the wind they are respectively intended to personify. Within a very recent period this building, which was more than half buried, has been exhumed, and many important facts have been discovered during the process of excavation. The interior has been cleared, and in the pavement may be seen the channels by which the water was conveyed to the machinery by whose agency the hour was indicated, when the absence of the sun rendered the dials described upon the marble faces of the tower of no avail. These dials have been tested and pronounced perfectly correct, by a no less celebrated authority than Delambre. The two arches on the left of the illustration are the only remaining portions of the aqueduct by which the necessary supply was conveyed, according to Stuart, from the spring in the grotto of Pan; it is a matter of gratulation alike to the antiquarian and the lover of the picturesque, that these have been spared. From the amount of excavation necessary to arrive at its basement, it is clear

that this portion of the town must have been raised, by ruins and atmospheric deposits, at least eight or nine feet above its original level.

The temple of Theseus, apart from the present town, and in a comparatively elevated and isolated position, built by Cimon, shortly after the battle of Salamis, is one of the most noble remains of the ancient magnificence of Athens, and the most perfect, if not the most beautiful, existing specimen of Grecian architecture. It is built of Pentelic marble; the roof, friezes, and cornices, still remain; and so gently has the hand of time pressed upon this venerable edifice, that the first impression of the mind in beholding it, is doubt of its antiquity. It was raised thirty years before the Parthenon, unlike which it appears to have been but sparingly supplied with sculptural decoration; but that which was so dedicated was of the highest merit, and remaining in an almost perfect condition, is most deeply interesting to the artist and the historian: supplying to the one models of beauty, and to the other the most undeniable data, upon which to establish the identity of this with the temple raised by the Athenians to the Hero-God.

After having been successively denominated the remains of the Palace of Pericles, of the temple of Jupiter Olympus (an unaccountable blunder), the Painted Portico, the Forum of the inner Cerameicus, the magnificent wreck of which the engraving given may convey a general idea, has been finally decided to have formed a portion of the Pantheon of Hadrian. For some time after this opinion had been started by Mr. Wilkins, and sanctioned by Sir William Gell, great doubts, despite the remarkable verification afforded by the language of Pausanias, remained as to its truth; but the Earl of Guildford has at length placed the matter beyond question. Some extensive excavations made under his personal direction resulted in the discovery of the Phrygian stone so minutely described by the enthusiastic traveller.

The portico forming the next illustration was for a long

time considered the only remaining portion of a temple dedicated to the Emperor Augustus, but it is now clearly established as having been one of the entrances to a market-place. This idea, suggested to the mind of Stuart by certain minute yet well marked variations in the proportion of the columns from those devoted to sacred purposes, has been sustained by research, and finally demonstrated to be correct by the discovery of an inscription which has put the question at rest for ever. In one of these the names of two prefects of the market are preserved; and another, still perfect, is an edict of Hadrian respecting the duties to be levied on certain articles of consumption, and regulating the sale of oils, &c. Nothing can be more picturesque than the present condition of this portico, the latest specimen of the pure Greek Art. Its coloring is rich and varied, while its state of ruin is precisely that in which the eye of the painter delights, sufficient to destroy all hardness or angularity, yet not so great as to rob it of one element of grandeur.

The building called the Monument of Philopappus, despite its somewhat fantastic elaboration of detail, is very remarkable and interesting; it was created either during the lifetime, or as a memorial immediately after his death, to Caius Julius Antiochus Philopappus, a descendant of the royalty of Syria, and an adopted citizen of Athens. It consists of a basement supporting a pilastrade of semicircular form, and presenting upon its concave surface three niches, containing sitting statues, and three recesses richly ornamented with the representation in strong relief of a Roman triumph. Upon the basement also were various sculptures in honor of the Emperor Trajan. These, and, indeed, all the decorative sculpture, &c., profusely lavished upon this building have suffered greatly. The two remaining statues are much dilapidated. From this point a magnificent view of the Acropolis is obtained, and few are the sights presented to the traveller, which surpass in historic interest or actual beauty that meeting his eye, to whichever point of the com-

pass he may turn when standing at the foot of this remarkably picturesque monument.

The ages which produced these marvellous works in architecture had other and different glories. Painting and sculpture reached the highest perfection; and poetry exhibited all the grace and vigor of the Athenian imagination. And though time has effaced all traces of the pencil of Parrhasius, Zeuxis, and Apelles, posterity has assigned them a place in the temple of fame beside Phidias and Praxiteles, whose works are, even at the present day, unrivalled for classical purity of design and perfection of execution. And after the city had passed her noon in art, and in political greatness, she became the mother of that philosophy at once subtile and sublime, which, even at the present hour, exerts a powerful influence over the human mind. This era in her history has been alluded to by Milton:

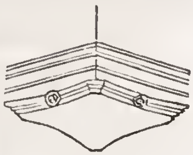
> "See there the olive grove of Academe,
> Plato's retirement, where the Attic bird
> Trills her thick-warbled notes the summer long;
> There flowery hill Hymettus with the sound
> Of bees' industrious murmur oft invites
> To studious musing; there Ilyssus rolls
> His whispering stream; within the wall then view
> The schools of ancient sages; his who bred
> Great Alexander to subdue the world,
> Lyceum there and painted Stoa next
> To sage philosophy next lend thine ear,
> From Heaven descended to the low roof'd house
> Of Socrates; see there his tenement,
> Whom, well inspired, the oracle pronounced
> Wisest of men; from whose mouth issued forth
> Mellifluous streams that water'd all the schools
> Of Academics old and new, with those
> Surnamed Peripatetics, and the sect
> Epicurean, and the Stoic severe."

Such is an outline of the remains of the chief Athenian

edifices, which link ancient times with the present, and which, as long as there is taste to appreciate or genius to imitate, must arrest the attention and command the admiration of all the generations of mankind.

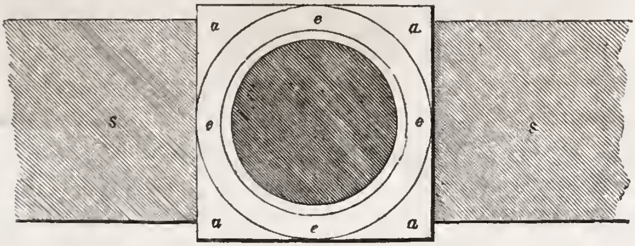
GLOSSARY.

Abacus.—The *plate* or shallow block forming the uppermost member of a capital is so called for the sake of distinction, for when a similar one is placed beneath the base of a column, it is called a *plinth*. It is sometimes square, and sometimes curved, forming on the plan segments of a circle, an ornament being introduced.



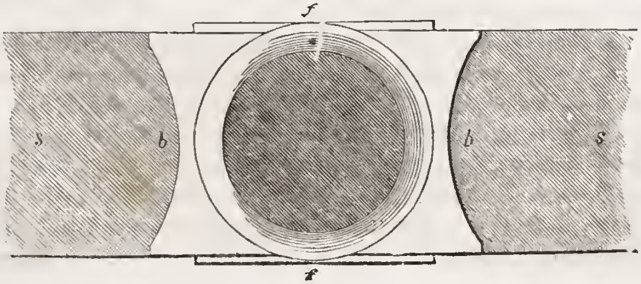
Abacus.

The Doric abacus is spoken of in this book, and is here shown in a plan of the capital and architrave; *a a a a* being the angles



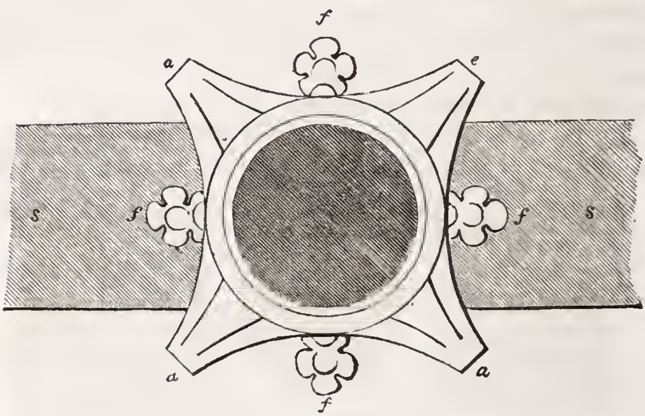
of the soffit or underside of the abacus which overhang the echinus *e e e e*; and *s s* the soffit of the architrave. From this, the relation between the abacus and architrave, and how much the former exceeds or projects out beyond the latter. will be better understood than by the engraving Fig. 1 p. 15, where the capital is shown only in *elevation*.

The next figure is still more indispensable for understanding the conformation of the Ionic capital. Here the abacus shows



itself only in front at *f f*, over the two voluted faces, the rest being concealed by the baluster sides *b b* of the capital, which extend beyond the abacus, and convert the general plan into more than a square. Although the channels and other details of the baluster sides are omitted, and only their general shape shown, the engraving explains how those sides are *reduced* by being hollowed out or curved concavely on the plan.

In the Corinthian Order, a similar curvature is given to the



abacus itself on all its four sides; the capital of this Order having that in common with the Doric, that it is quite regular. One great point of difference between the Doric and Corinthian abacus is, that in the former the angles are unsupported, and overhang the circular body of the capital, while in the Corinthian Order they extend outwards diagonally, as *a a a a* in the figure, and supported by the *caulicoli* or small volutes, which they in turn serve to cover. The letters *f f f f* indicate the rosettes or flowers on the four faces of the abacus.

Amphiprostyle.—A building having a portico at both ends.

Amphitheatre.—A theatre of an elliptical form, or in other words, a double theatre, produced by building two, end to end.

Ancones.

Ancones or Trusses.—Ornaments in the cornice of an Ionic doorway, resembling modillions placed vertically.

Amulet.—The mouldings at the lower part of the echinus in Doric capitals. A small square moulding used to separate other mouldings.

Antæ.—Square pillars or pilasters, attached to a wall. They have capitals different from those of the columns with which they are associated.

Apophyge.—The small faciæ by which the shaft is attached to the fillet of the base.

Apteral.—A temple without columns at the ends.

Areostyle.—An arrangement of columns, when four diameters are allowed between them.

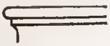
Architrave.—The lowest member of the entablature; also, mouldings round doors and windows.

Archivolt.—The interior face of an arch, between the imposts.

Arris.—The meeting of two surfaces producing an angle.

Area.—An open space within a building.

Astragal.—A semi-circular moulding.



Astragal.

Attic.—A small height of panelling above the cornice; also, the upper story of a house when the walls are perpendicular.

Aisles.—The spaces on each side of a nave.

Almery.—A niche or closet introduced in the walls of churches or cathedrals, intended for the keeping of valuable articles belonging to the religious service.

Almonry.—The building in which alms are distributed.

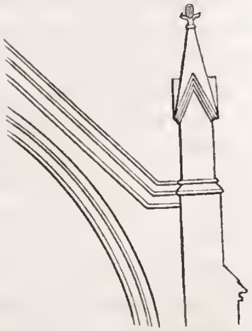
Almery.

Ambo.—A pulpit or raised platform.

Arch-Buttress, or Flying-Buttress.—An arch introduced for the purpose of supporting or appearing to support a spire, or one springing over the roof of an aisle, and a butting against the wall of the clerestory.

Aspersorium.—The holy water basin.

Auditorium.—The nave or body of the church, where the people meet for worship.



Arch-Buttress, or Flying-Buttress.

Antefixæ.—Called by some, *Greek Tiles*,—upright ornamental blocks placed at intervals on the cornice along the roof, to conceal or rather terminate the ridges formed by the overlapping of the roof.

Æsthetic.—Artistic.

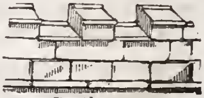
Astylar.—A term that expresses the absence of columns or pilasters, where they might else be supposed to occur.

Axis.—An imaginary line through the centre of a column, &c.

Baptistry.—The place in which the rite of baptism is performed.

Bartizan.—A turret over the roof, and within the parapet of any building.

Battlement.—An indented and sometimes perforated parapet.



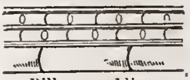
Battlement.

Bay.—The space between the ribs of a groined roof; also, the part of a window between the mullions.

Bay-Window.—" A projecting window, rising from the ground, or basement, in a semi-octagon, semi-hexagon, or polygonal form."

Benetier.—A vessel for holy water, usually placed at the entrance of a church.

Billet-moulding.—Cylindrical blocks placed at short but equal distances from each other, in a hollow moulding.



Billet-moulding.

Boss.—A carved ornament at the intersection of the ribs in a groined roof.

Brasses.—Brass plates let into the pavement of ecclesiastical buildings over or near tombs. All of these have an engraving of some sort, and many of them are admirably designed, and elaborately engraven.

Buttress.—A projection from a wall built between the windows and at the angles of a building, having the double purpose, in Gothic structure, of strength and ornament. They are of various forms, according to the style of architecture.

Buttress.

Bed-mouldings.—The mouldings beneath the corona or principal projecting member of a cornice.

Branches.—The ribs of a groined roof.

Bracket.—A projection from the face of a well to carry sculpture, or support some weight.

Blocking Course.—A solid course of masonry, above a cornice.

Base.—The part of a column on which the shaft rests. The term is also used to signify the lower part of a wall.

Bandelet.—A very narrow moulding, of the same form as the band.

Band.—A moulding with a square profile.

Balustrade.—A range of small pillars or balusters upon a plinth, and surmounted by a cornice or coping.

Baluster.—A small pillar, the form of which may be varied at pleasure, used in balustrades.

Balcony.—A projection from the face of a wall, supported by columns or consoles, and usually surrounded by a balustrade.

Cable.—A moulding representing a cable.

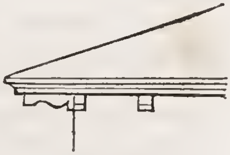
Caissons.—Sunk panels in ceilings or in soffits.

Campana.—The part of a Corinthian capital on which the leaves are placed.

Cantilevers.—Trusses under the modillions of a frieze.

Capital.—The part of a column on which a column rests on the shaft.

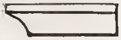
Cartouches.—Modillions or blocks supporting the eaves of a house.



Cartouches.

Casement.—The frame of a window or light: also a moulding the same as the scotia.

Cavetto.—A hollow moulding, one quarter of a circle.



Cavetto.

Channel.—A canal or groove sunk in the face of any work.

Colonnade.—A row of columns supporting an entablature.

Column.—A round pillar, having a shaft and capital, and generally a base.

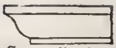
Coping.—A sloping stone on the top of a wall, to throw off the rain-water.

Corbel.—A projection from the surface of a wall, to carry a weight, and generally ornamented.

Cornice.—The upper division of an entablature, composed of several members, and varying according to the order.

Corona.—A large square member of a cornice, between the cymatium and bed-mouldings. It is intended to protect the parts beneath it, and has a considerable projection. It is sometimes called the larmier, but more frequently the drip.

Cyma Recta.—A compound moulding, hollow in the upper, round in the lower part.



Cyma Recta.

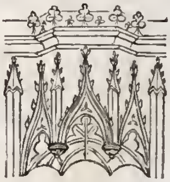
Cyma Reversa.—A moulding, the reverse of the cyma recta.

Cymatium.—The upper moulding of an entablature.

Cable-moulding.—A moulding used in Norman architecture, and deriving its name from its form.

Cable-moulding.

Canopy.—An ornamental projection over doors, windows, and niches, chiefly introduced in the Decorated and Perpendicular English.



Canopy.

Carol.—A small closet in a cloister.

Catherine-wheel Window.—A circular window, usually with a rich radiating tracery.

Chapels.—Small buildings attached to cathedrals and large churches.

Chantry.—A small chapel at the side of a church.

Chevron, or Zig-Zag.—A characteristic moulding in Norman buildings.

Choir.—The space eastward of the cross in churches having that form, and between the nave and high altar.

Cinquefoil.—An ornament representing the leaves of a flower or leaf, used in Gothic architecture.

Cinquefoil.

Clere-story.—The upper story or row of windows in a Gothic church.

Cloisters.—Covered passage ways to different parts of an ecclesiastical building.

Crocket.—An ornament resembling a bunch of flowers or foliage, chiefly used at the angles of pinnacles and canopies.

Crypt.—A vaulted chamber under a church, generally under the eastern end; and used either as a place of sepulture, an oratory, or baptistry.

Crocket.

Cusps.—The ornaments at the points of the tracery in Gothic windows; or according to some, the arcs which the ornaments terminate.

Caryatides.—Pillars where human figures, instead of columns, are used to support an entablature.

Dado, or Die.—The plain part of a pedestal.


Dentils.

Dentils.—Square projecting blocks in the bed-moulds of the entablatures. They are so called from a fancied resemblance to a row of teeth.

Dodecastyle.—A building with twelve columns in front.

Donjon, or Keep.—A massive tower in ancient castles, usually in the centre.


Dovetail-moulding.

Dovetail-moulding.—A characteristic Norman moulding.

Dungeon.—The vault for prisoners, usually the basement of the Donjon.


Echinus.

Echinus.—An egg-shaped ornament in the Ionic capital.

Entablature.—The uppermost division of a column, supported by the shaft.

Eustyle.—Two and a quarter diameters between the columns.

Embrasure or Crenelle.—A splayed opening in a wall; an opening in a battlement.

Elevation.—An *upright plan* of a building or any part of a building, showing its exact form and dimensions as they actually exist.

Entasis.—A slightly convex curvature given in execution to the outline of the shaft of a column, just sufficient to counteract and correct the appearance, or fancied appearance, of curvature in a contrary direction, (i. e. concavely,) which might else take place, and cause the middle of the shaft to appear thinner than it really is.

Epistylum.—The architrave or horizontal course resting immediately upon the columns. Hence we should denote as *Epistylar Arcuation* that system in which columns support arches instead of horizontal architraves and entablatures.

Epitithedas.—The cymatium on the sloping or *raking* cornices of a pediment, which *superimposed* moulding (as its name implies) was frequently largely developed, and enriched with an ornamental pattern.

Feathering or Foliation.—Smalls arcs or foils in the tracery of Gothic windows. According to the numbers uniting, they are called trefoils, quatrefoils, cinquefoils, or multifoils.

Finial.—The ornament which crowns a pinnacle on canopy.

Font.—A vase used for baptism.

Façade.—The elevation or view of the principal front of any building.

Fascia, or Facia.—A broad flat member, in an architrave, cornice, or pedestal.

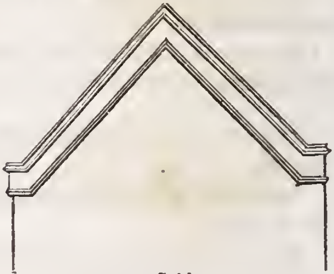
Fillet.—A small square member, dividing mouldings.

Flutings.—Perpendicular channels in the shaft of a column.

Frieze.—The middle division of an entablature.

Fenestration.—In contra-distinction from columniation, the system of construction and mode of design marked by windows.

Gable.—The triangular masonry or woodwork at the end of a roof. Some of the old gable ends are curiously carved.



Gable.

Glyphs.—Vertical channels in the Doric frieze.

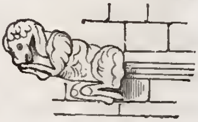
Guttæ.—Ornaments resembling drops, under the mutules of the Doric entablature.

Guttæ

Gablet.—A small gable in screens, &c.

Gargoyle.—The projecting water-spout, generally ornamented with the head of a man, a monster, or some appropriate emblem.

Groin.—The lines formed by the intersection of two or more vaults.



Gargoyle.

Heptastyle.—A building with seven colums in front.

Hexastyle.—A building with six columns in front.

Hatched-moulding.—A moulding used in Norman Architecture, with ornaments of a triangular form, and having the appearance of being cut with a hatchet.

Hatched-moulding.

Hovel.—A *niche*, or canopy for a statue.

Hypotrachelium.—The necking of a capital introduced between the capital itself and the shaft of the column.

Impost.—The abacus which crowns a pilaster or pier, and from which an arch springs; also, the capital of a pilaster which sustains an arch.

INTERCOLUMNIATION.—The distance between one column and another.

JUBE.—A gallery or rood-loft over the choir, to the front of which was generally attached a pulpit.

KEEP.—The most elevated and innermost tower of a castle.

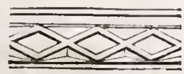
KNOB.—The boss at the crowning of a groin.

LABEL, OR HOOD-MOULDING.—The outer moulding over doors or windows.

LAVATORY.—A stone basin attached to the altar, used by the priest during mass to dip or wash his hands.

LETTERN, OR LECTERN.—A reading-desk, commonly of brass.

LOZENGE-MOULDING.—A moulding used in Norman architecture.



Lozenge-muulding.

METOPE.—The interval between the triglyphs in a Doric frieze, often ornamented with sculptures.

Metope.

MODILLION.—An ornament in the Corinthian and Composite orders, resembling a bracket.

MUTULES.—Small block ornaments under the corona in the Doric order.

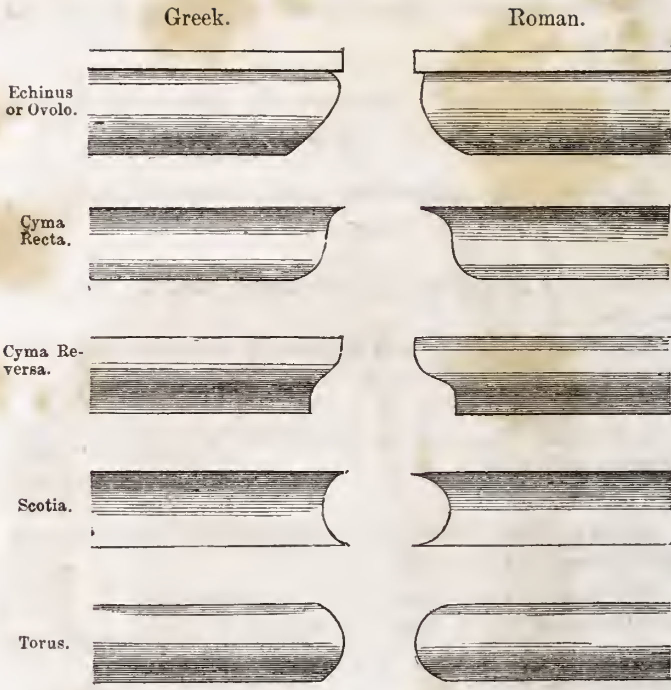
MULLIONS.—The upright shafts dividing a window into separate light.

MISERERES.—Shelving seats in the stalls of churches and cathedrals.

MERLON.—The solid part of an embattled parapet.

MACHICOLATIONS.—The perpendicular openings left between the corbels of a battlement over gateways and doors, intended to afford facilities for annoying assailants.

MOULDINGS.—The principal mouldings and the difference of their profiles in the Grecian and Roman styles are here exhibited.



Monotriglyphic.—That mode of intercolumniation in the Doric Order, according to which there is only a single triglyph over each intercolumn.

Module.—The semi-diameter of the column, or 30 minutes.

Minute.—The sixtieth part of the diameter of the column, as a proportional measure. Minutes are written thus, 8′, that is, eight minutes.

Nave.—The central division of a church between the aisles.

Ovolo.—A convex moulding, a quarter of a circle, and sometimes called a quarter round.

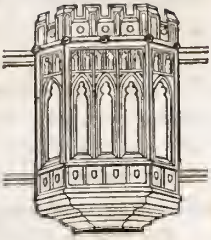
Ovolo.

TEMPLE OF THESUS

page 275.

ORATORY.—A private chapel for prayer.

ORIEL.—A window projecting from a wall.



Oriel.

PARAPET.—A wall about breast high, at the top of a house, or on a bridge, intended as a defence. It is sometimes ornamented, sometimes plain.

PATERA.—An ornament in a frieze, resembling a goblet.

PEDESTAL.—A square piece of masonry supporting the base of the column, and consisting of a base, die and cornice.

PEDIMENT.—The triangular form above the columns in the front and back of a building; also the same over windows and doors.

PENTASTYLE.—A portico of five columns.

PERIPTERAL.—A temple having columns all round.

PIER.—A solid pilaster or column from which an arch springs, or carrying a weight; also, the solid mass between the doors or windows of a building, or between the arches of a bridge.

PILASTER.—This term is not synonymous with the word column. In the latter, a regular and almost undeviating proportion is maintained between the several parts, bnt in the former, the same arrangement of parts is not adopted.

PLATBAND.—A square member, with a projection less than either the height or breadth.

PLINTH.—A solid mass under the base of a column.

PODIUM.—A running pedestal, supporting a series of columns round a building.

PORTICO.—A horizontal projection in the front of a building, supported by columns.

PIX.—The shrine to contain the host or consecrated wafers.

PORCH.—A small covered entrance into a building.

PANEL.—A small compartment enclosed with mouldings, and generally decorated with an ornament, or sculpture.

PENDENT.—An ornament hanging from a roof.

PERCHES.—Brackets in churches, for images or candlesticks.


Pinnacle.

PINNACLE.—A small spire, or pointed termination to towers, turrets, and buttresses, generally with four sides, and more or less ornamented.

PLAN.—A plan may be familiarly described as an architectural *map*, or map of a building. To define it more exactly,—a plan is a *horizontal section* supposed to be taken on the level of the floor through the solid parts of the fabric, walls, columns, &c., so as to show their various thicknesses and situations.

POLYSTYLE.—Having a number of columns. Where columns occur behind columns, as where a portico has inner columns, such portico may be termed a *polystyle*.

PROFILE.—The outline of a series of mouldings, or of any other parts, as shown by a section through them.

PULVINATED.—A frieze whose face is convex instead of plain is said to be *pulvinated*, from its supposed resemblance to that side of a cushion which swells out when pressed.


Quatrefoil.

QUATREFOIL.—An ornament representing four leaves of a flower, formed within a circle.

RUSTIC.—Stone or compo work, channelled vertically and horizontally.

ROOD.—A cross with a figure of our Saviour on it.

ROOD LOFT.—A gallery generally over the screen, or at the entrance of the choir, in which a rood was in former times placed.

RAKING CORNICES.—A term applied to the inclined cornices on the sloping side of a pediment.

SCOTIA.—A hollow moulding, chiefly used in the base of the Ionic column.

SCROLL.—A spiral; the volute of the Ionic capital.

SHAFT.—That part of a column between the capital and base.

SPIRE.—The pyramidical structure crowning a tower or turret.


Spandril.

SPANDRIL.—The triangular space between an arch and the right angle above it.

STALLS.—Elevated seats on the sides of a choir in cathedrals, with canopies over them, appropriated for ecclesiastics.

STANCHEON.—The upright bar or mullion which divides a window into bays.

Steeple.—A tower rising above the roof of a church.

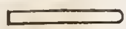
Section.—A vertical plan of the interior of a building, showing it as it would appear upon an upright plane *cutting through it.*

Soffit.—From the Italian *soffitto,* a ceiling; the under surface of any projecting moulding or member.

Stylobate.—That part of a structure on which an order is raised, and on which the columns immediately stand. The term is, however, restricted to what partakes of the character of a pedestal, and not to a mere plinth or socle on the one hand, or tc a lower fenestrated floor on the other.

Tetrastyle.—A building with four columns in front.

Torus.—A semi-circular moulding.


Torus.

Triglyph.—The vertical channels in the Doric frieze.


Triglyph.

Tympanum.—The triangular surface enclosed by the pediment. In the ancient temples it was frequently decorated with sculptures.

Tabernacle.—A stall or niche detached fom the wall, with a canopy over it.

Tablet.—A projecting moulding, more particularly that uuder a window.

Transept.—That part of a church or cathedral which runs north and south, forming the arms of a cross.

Tracery.—The frame-work and ornament in the head of a window or screen.

Transom.—The horizontal bar dividing a window into lights.

Trefoil.—An ornament representing three leaves of a flower, formed within a circle.


Trefoil.

Tudor Flower.—An ornament employed for open parapets.

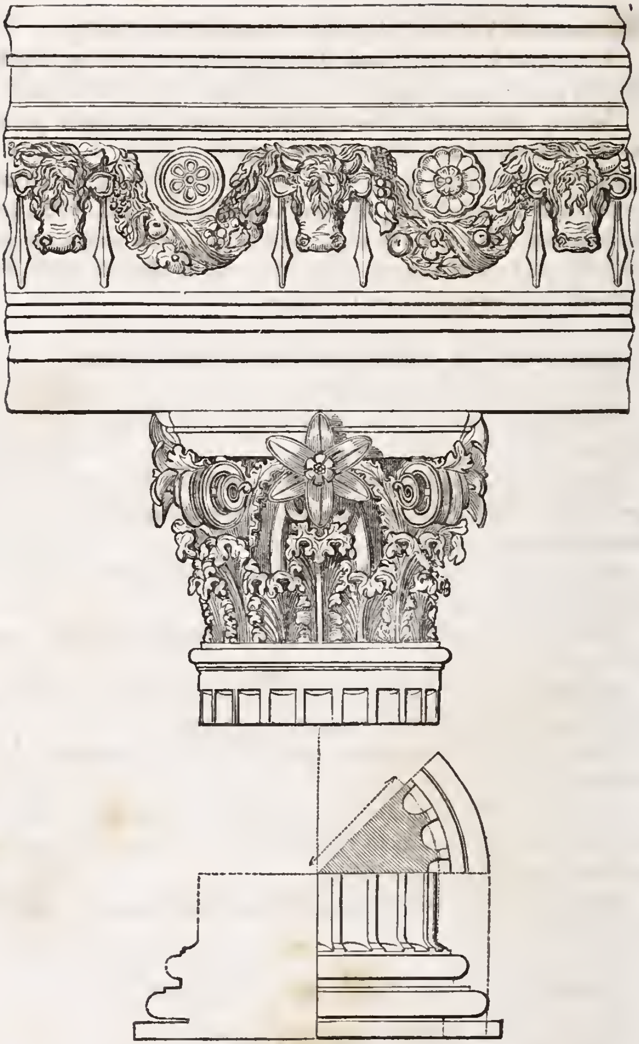
Undercroft.—The crypt or vault of a church.

Volute.—The spirals on an Ionic capital.

Vestibule.—The large hall or passage.

Weepers.—The statues of Grief, at the base of a tomb or monument.

Zig-Zag.—See Chevron.



THIS ENGRAVING SHOWS THE FRIEZE, CAPITAL AND BASE EMPLOYED IN THE FRONT OF ST. PAUL'S SCHOOL, ST. PAUL'S CHURCH YARD, LONDON.

RUDIMENTS

OF THE

ART OF BUILDING.

CONTENTS.

RUDIMENTS

OF THE

ART OF BUILDING.

SECTION I.

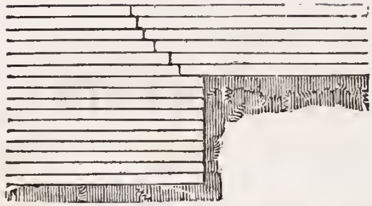
GENERAL PRINCIPLES OF CONSTRUCTION.

FOUNDATIONS.

1. In preparing the foundation for any building, there are two sources of failure which must be carefully guarded against: viz., inequality of settlement, and lateral escape of the supporting material; and, if these radical defects can be guarded against, there is scarcely any situation in which a good foundation may not be obtained.

2. *Natural Foundations.*—The best foundation is a *natural* one, such as a stratum of rock, or compact gravel. If circumstances prevent the work being commenced from the same level throughout, the ground must be carefully *benched out*, *i. e.*, cut into horizontal steps, so that the courses may all be perfectly level. It must also be borne in mind that all work will settle, more or less, according to the perfection of the joints, and therefore in these cases it is best to bring up the foundations to a uniform level, with large blocks of stone, or with concrete, before commencing the superstructure, which would otherwise settle most over the deepest parts, on account of the greater number of mortar joints, and thus cause unsightly fractures, as shown in fig. 1.

Fig. 1.



3. Many soils form excellent foundations when kept from the weather, which are worthless when this cannot be effected. Thus blue shale, which is often so hard when the ground is first opened as to require blasting with gunpowder, will, after a few days' exposure, slake and run into sludge. In dealing with soils of this kind nothing is required but to keep them from the action of the atmosphere. This is best done by covering them with a layer of concrete, which is an artificial rock, made of sand and gravel, cemented with a small quantity of lime. For want of this precaution many buildings have been fractured from top to bottom by the expansion and contraction of their clay foundations during the alternations of drought and moisture, to which they have been exposed in successive seasons.

4. *Artificial Foundations.*—Where the ground in its natural state is too soft to bear the weight of the proposed structure, recourse must be had to artificial means of support, and, in doing this, whatever mode of construction be adopted, the principle must always be that of extending the bearing surface as much as possible ; just in the same way, that, by placing a plank over a dangerous piece of ice, a couple of men can pass over a spot which would not bear the weight of a child. There are many ways of doing this—as by a thick layer of concrete, or by layers of planking, or by a net-work of timber, or these different methods may be combined. The weight may also be distributed over the entire area of the foundation by inverted arches.

5. The use of timber is objectionable where it cannot be

kept constantly wet, as alternations of dryness and moisture soon cause it to rot, and for this reason concrete is very extensively used in situations where timber would be liable to decay.

6. In the case of a foundation partly natural and partly artificial, the utmost care and circumspection are required to avoid unsightly fractures in the superstructure; and it cannot be too strongly impressed on the mind of the reader, that it is not an *unyielding*, but a *uniformly yielding* foundation that is required, and that it is not the *amount*, so much as the *inequality*, of settlement that does the mischief.

The second great principle which we laid down at the commencement of this section was—To prevent the lateral escape of the supporting material. This is especially necessary when building in running sand, or soft, buttery clay, which would ooze out from below the work, and allow the superstructure to sink. In soils of this kind, in addition to protecting the surface with planking, concrete, or timber, the whole area of the foundation must be inclosed with piles driven close together;—this is called *sheet-piling*.

7. Where there is a hard stratum below the soft ground, but at too great a depth to allow of the solid work being brought up from it without greater expense than the circumstances of the case will allow, it is usual to drive down wooden piles, shod with iron, until their bottoms are firmly fixed in the hard ground. The upper ends of the piles are then cut off level, and covered with a platform of timber on which the work is built in the usual way.

8. Where a firm foundation is required to be formed in a situation where no firm bottom can be found within an available depth, piles are driven, to consolidate the mass, a few feet apart over the whole area of the foundation, which is surrounded by a row of sheet-piling to prevent the escape of the soil; the space between the pile heads is then filled to the depth of several feet with stones or concrete, and the

whole is covered with a timber platform, on which to commence the solid work.

9. *Foundations in Water.*—Hitherto we have been describing ordinary foundations; we now come to those cases in which water interferes with the operations of the builder, oftentimes causing no little trouble, anxiety, and expense.

Foundations in water may be divided under three heads:

1st. Foundations formed wholly with piles:

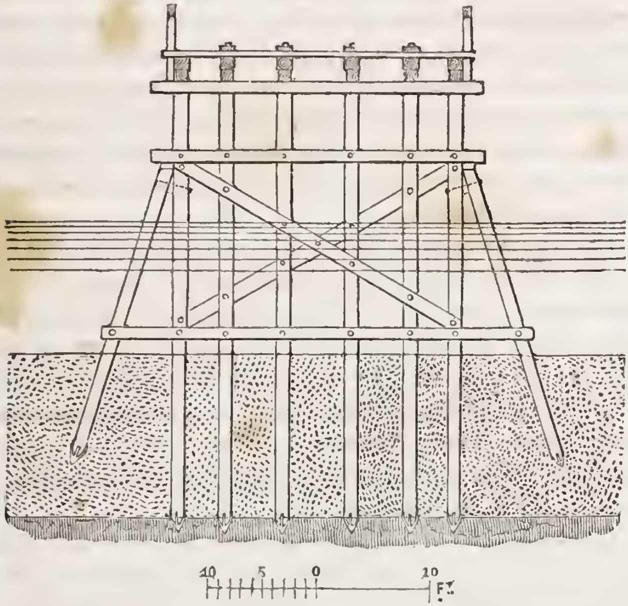
2d. Solid foundations laid *on* the surface of the ground, either in its natural state, or roughly leveled by dredging:

3d. Solid foundations laid *below* the surface, the ground being laid dry by cofferdams.

10. *Foundations formed wholly of Piles.*—The simplest foundations of this kind are those formed by rows of wooden piles braced together so as to form a skeleton pier for the support of horizontal beams; and this plan is often adopted in building jetties, piers of wooden bridges, and similar erections where the expense precludes the adoption of a more permanent mode of construction; an example of this kind is shown in fig. 2.

In deep water, the bracing of the piles becomes a difficult matter, and an ingenious expedient for effecting this was made use of by Mr. Walker, in the erection of the Ouse Bridge, on the Leeds and Selby Railway, A.D. 1840. This consisted in rounding the piles to which the braces are attached for a portion of their length, to allow the cast-iron sockets in which they rest to descend and take a solid bearing upon the square shoulders of the brace-piles. After the brace-piles were driven, the braces were bolted into their sockets and dropped down to their required position, and their upper ends were then brought to their places and bolted to the superstructure.

Fig. 2.



11. There is always, however, a great objection to the use of piles partly above and partly under water, namely, that, from the alternations of dryness and moisture, they soon decay at the water-line, and erections of timber require extensive repairs from this cause. In tidal waters, too, they are often rapidly destroyed by the worm, unless great expense is undergone in sheathing them with copper.

To obviate the inconveniences attending the use of timber, cast-iron is sometimes used as a material for piles ; but this again is objectionable in salt water, as the action of the sea-water upon the iron converts it into a soft substance which can be cut with a knife, resembling the Cumberland lead used for pencils.

12. In England, in situations where a firm hold cannot be obtained for a pile of the ordinary shape, such as shifting sand, Mitchell's patent screw-piles are used with great advantage. These piles terminate at the bottom in a large

iron screw 4 ft. in diameter, which, being screwed into the ground, gives a firm foot-hold to the pile. This is a very simple and efficient mode of obtaining a foundation where all other means would fail, and has been used in erecting light-houses on sand-banks with great success. The Maplin sand light-house at the mouth of the Thames, and the Fleetwood light-house, at Fleetwood, in Lancashire, both erected A. D. 1840, may be instanced.

13. An ingenious system of cast-iron piling was adopted by Mr. Tierney Clark in the erection of the Town Pier at Gravesend, Kent, A. D. 1834, in forming a foundation for the cast-iron columns, supporting the superstructure of the T head of the pier. Under the site of each column were driven three cast-iron piles, on which an adjusting plate was firmly keyed, forming a broad base for the support of the column, which was adjusted to its correct position, and bolted down to the adjusting plate.

14. A kind of foundation on the same principle as piling has been lately much used in situations where ordinary piling cannot be resorted to with advantage. The method referred to consists in sinking hollow cast-iron cylinders until a hard bottom is reached. The interior of the cylinder is then pumped dry, and filled up with concrete, or some equally solid material, thus making it a solid pier on which to erect the superstructure. The cylinders are made in lengths, which are successively bolted together as each previous length is lowered, the excavation going on at the bottom, which is kept dry by pumping. It often happens, however, in sinking through sand, that the pressure of the water is so great as to blow up the sand at the bottom of the cylinder; and when this is the case, the operation is carried on by means of a large auger, called a miser, which excavates and brings up the materials without the necessity of pumping out the water. The lower edge of the bottom length of each cylinder is made with a sharp edge, to enable it to penetrate the soil with greater ease, and to enter the hard

bottom stratum on which the work is to rest. This method was adopted by Mr. Redman in the erection of the Terrace Pier at Gravesend, Kent, finished A. D. 1845.

15. Before closing our remarks on pile foundations, we must mention a very curious system of carrying up a foundation through loose, wet sand, which is practised in India and China, and is strictly analogous to the sinking of cast-iron cylinders just described.

It consists in sinking a series of wells close together, which are afterwards arched over separately, and covered with a system of vaulting on which the superstructure is raised. The method of sinking these wells is to dig down, as far as practicable, without a lining of masonry, or until water is reached ; a wooden curb is then placed at the bottom of the excavation, and a brick cylinder raised upon it to the height of 3 or 4 ft. above the ground. As soon as the work is sufficiently set, the curb and the superincumbent brick-work are lowered by excavating the ground under the sides of the curb, the peculiarity of the process being that the well-sinker works under water, frequently remaining submerged more than a minute at a time. These cylinders have been occasionally sunk to a depth of 40 ft.

16. *Solid Foundations simply laid on the Surface of the Ground.*—Where the site of the intended structure is perfectly firm, and there is no danger of the work being undermined by any scour, it will be sufficient to place the materials on the natural bottom, the inequalities of surface being first removed by dredging or blasting.

17. *Pierre perdue.*—The simplest mode of proceeding is to throw down masses of stone at random over the site of the work until the mass reaches the surface of the water, above which the work can be carried on in the usual manner. This is called a foundation of "*pierre perdue,*" or random work, and is used for breakwaters, foundations of sea-walls, and similar works.

18. *Coursed Masonry.*—Another way, much used in harbor work, is to build up the work from the bottom (which must be first roughly leveled) with large stones, carefully lowered into their places ; and this is a very successful method where the stones are of sufficient size and weight to enable the work to withstand the run of the sea. The diving-bell affords a ready means of verifying the position of each stone as it is lowered.

19. *Béton.*—On the continent, foundations under water are frequently executed with blocks of béton or hydraulic concrete, which has the property of setting under water. The site of the work is first inclosed with a row of sheet piling, which protects the béton from disturbance until it has set. This system is of very ancient date, being described by Vitruvius, and was practised by the Romans, who have left us many examples of it on the coast of Italy. The French engineers have used béton in the works at Algiers, in large blocks of 324 cubic feet, which were floated out and allowed to drop into their places from slings. This method, which proved perfectly successful, was adopted in consequence of the smaller blocks first used being displaced and destroyed by the force of the sea.

20. *Caissons.*—A caisson is a chest of timber, which is floated over the site of the work, and, being kept in its place by guide piles, is loaded with stone until it rests firmly on the ground. The masonry is then built on the bottom of the caisson, and when the work reaches the level of the water the sides of the caisson are removed.

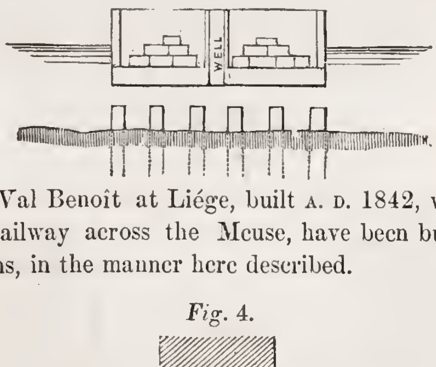
This method of building has been much used on the continent of Europe.

21. An improvement on the above method consists in dredging out the ground to a considerable depth, and putting in a thick layer of béton on which to rest the bottom of the caisson.

22. There is a third method of applying caissons which is

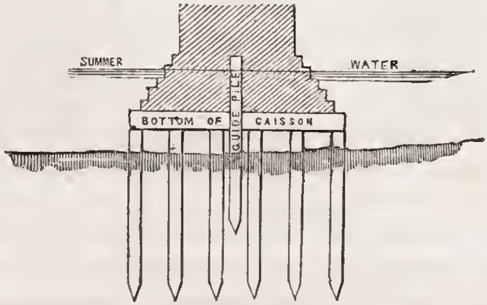
practised on the continent of Europe, and which is free from the objections which commonly attend the use of caissons. A firm foundation is first formed by driving piles a few feet apart over the whole site of the foundation. The tops of the piles are then sawn off under water just enough above the ground to allow of their being all cut to the same level The caisson is then floated over the piles, and, when in its proper position, is sunk upon them, being kept in its place by a few piles left standing above the others, the water being kept out of the caisson by a kind of well, constructed round each of these internal guide piles, which are built up into the masonry. This method of building in caissons on pile foundations is shown in figs. 3 and 4. The piers of the

Fig. 3.



Pont du Val Benoît at Liége, built A. D. 1842, which carries the railway across the Meuse, have been built on pile foundations, in the manner here described.

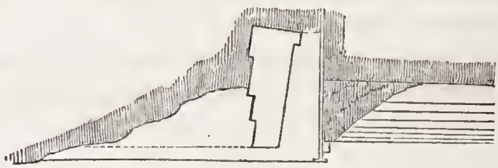
Fig. 4.



23. *Solid Foundations laid in Cofferdams.*—There are many circumstances under which it becomes necessary to

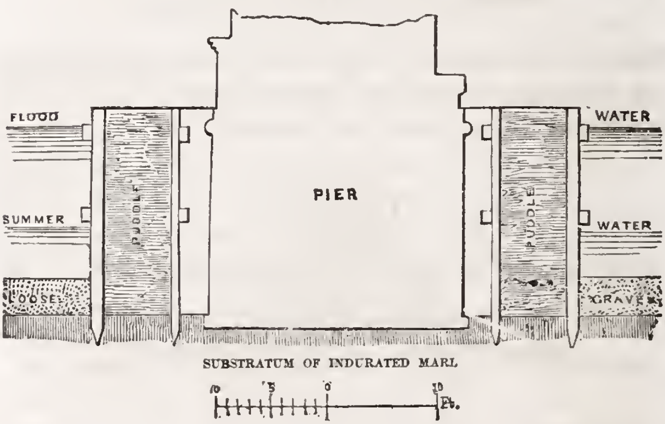
lay the bottom dry before commencing operations. This is done by inclosing the site of the foundation with a water-tight wall of timber, from within which the water can be pumped out by steam power or otherwise. Sometimes, in shallow water, it is sufficient to drive a single row of piles only, the outside being protected with clay, as shown in fig 5 ; but in deep water two or even four rows of piles will be

Fig, 5.



required, the space between them being filled in with well-rammed *puddle*, so as to form a solid water-tight mass. (See fig 6.) The great difficulties in the construction of a

Fig. 6.



cofferdam are—1st, to keep it water-tight ; and, 2nd, to support the sides against the pressure of the water outside, which in tidal waters is sometimes so great as to render it necessary to allow a dam to fill to prevent its being crushed.

24. In order to save timber, and to avoid the difficulty of keeping out the bottom springs, it has been proposed by a French engineer, after driving the outer row, to dredge out the area thus inclosed, and fill it up to a certain height with béton. The cofferdam is then to be completed by driving an inner row of piles resting on the béton, and puddling between the two rows in the usual manner; and the masonry is carried up on the béton foundation thus prepared. This construction is shown in fig. 7.

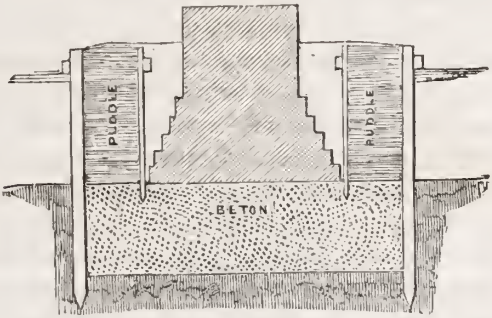


Fig. 7.

25. Concrete is a valuable material when applied in a proper manner, viz., in underground works where it is confined on all sides, and is, consequently, subjected to little cross strain; but it is not fit to be used *above* ground as a substitute for masonry, and will not bear exposure to water.

26. Concrete is made of gravel, sand, and ground lime, mixed together with water; the slaking of the lime taking place whilst in contact with the sand and gravel. It is difficult to give any definite proportions for the several ingredients, but the principle to be followed in proportioning the several quantities of sand and stones should be to form as much as possible a solid mass, for which purpose it is desirable that the stones should be of various sizes, and angular rather than rounded. The common material is unscreened gravel, containing a considerable portion of sand and large and small pebbles, but small irregular fragments of broken

stone, granite chippings, and the like, are of great service, as they interlace each other and bind the mass together. The proportion of lime to sand should be such as is best suited to form a cement to connect the stones. This must depend in a great measure on the quality of the lime used; the pure limes requiring a great proportion of sand, whilst the stone limes, and those containing alumina, silica, and metallic oxides, require a much smaller proportion.

27. The lime and gravel should be thoroughly incorporated by being repeatedly turned over with shovels, sufficient water being added to ensure the thorough slaking of the lime without drowning it. Concrete should not be thrown into water, because ordinary stone lime will not set under such circumstances; and it should be carefully protected from any wash or run of water, which would have the effect of washing out the lime, and leaving the concrete in the state of loose gravel. Concrete made in the way just described swells slightly before setting, from the expansion due to the slaking of the lime, and does not return to its original bulk. This property makes it valuable for underpinning foundations and similar purposes.

28. *Béton.*—Béton may be considered as hydraulic concrete; that is, concrete made with hydraulic lime; and is chiefly used in submarine works, as a substitute for masonry, in situations where the bottom cannot be laid dry. It differs from ordinary concrete inasmuch as the lime must be slaked before mixing with the other ingredients, and it is usual to make the lime and sand into mortar before adding the stones. Concrete also is used hot, whilst béton is allowed to stand before being used, in order to ensure the perfect slaking of every particle of lime. Belidor directs that the mortar shall first be made, with puzzolana, sand, and quicklime. When the mortar is thoroughly mixed, the stones are to be thrown in (not larger than a hen's egg), and also iron dross well pounded; the whole is then to be thoroughly incorpor-

ated, and left for twenty-four hours. The proportions are to be as follows :—

Puzzolana .	12	parts.
Sand	6	"
Good quicklime	9	"
Small stones .	13	"
Ground slag .	3	"
	43	

The béton is to be lowered into the water in a box, with a bottom so constructed that it can be opened, and its contents discharged, by pulling a cord, so as to deposit the béton on the bottom without having to fall through a depth of water, which might wash away the lime. For the same reason it is necessary, before commencing, to lay the béton, to surround the site with sheet-piling, to protect it from the action of the water, and to guard against the danger of the softer portions of the work being carried away by tempests before they become consolidated.

29. The ordinary method of using béton on the Continent is in alternate layers of béton and rubble stone. A layer of béton, about a foot in thickness, is first spread over the whole area of the foundation, and on this is laid a stratum of rubble, which, sinking into the soft béton, becomes thoroughly incorporated with it. On this is laid another layer of béton, followed by another course of rubble ; this system being pursued until the work reaches the intended height.

30. *Pile-driving.*—The usual method of pile-driving is by a succession of blows given by a heavy block of wood or iron (called a monkey, or ram, or tup), which is raised by a rope or chain passed over a pulley fixed at the top of an upright frame of timber, and allowed to fall freely on the head of the pile to be driven. There are a large number of pile-drivers of different styles in use. The one most commonly used in the United States is Captain Cram's.

31. In selecting timber for piles, care should be taken to choose that which is straight-grained and free from knots and ring shakes. Larch, fir, beech, and oak, are the woods most esteemed. In situations exposed to the worm, there is little difference in the durability of the best and the worst timber, if unprepared, and, therefore, it is always safest to use some preserving process.

32. Piles which have to be driven through hard ground require to be *rung*, that is, to have an iron hoop fixed tightly on their heads, to prevent them from splitting, and also to be *shod* with iron shoes ; the shoes may be of wrought or of cast iron. For single piles the point of the shoe is placed in the centre of the pile ; but for sheet-piling, the shoes are made not with a point, but with an edge, which is not level, but slightly inclined, so as in driving to give the pile a *drift* towards the pile last driven, by which means a close contact is ensured. Great care is required, in shoeing a pile, to ensure that the shoe is driven perfectly home The advantage of a cast-iron shoe is, that the inside can be formed with a square abutment on which the pile rests, whilst a wrought-iron shoe has to be driven up until the toe of the pile is *wedged* tight, and, as the force with which the pile is driven into the ground greatly exceeds that with which the shoe is driven on the pile, it will often happen that the shoe will burst open, and allow the point of the pile to be crushed before it is down to its full depth.

33. Sheeting piles should be carefully fitted to each other before driving, otherwise they cannot be expected to come in close contact when driven In some few cases it is worth while to groove and tongue the edges, but this is seldom done, and if the piles are perfectly parallel and truly driven, the swelling of the wood when exposed to moisture will generally secure a tight joint.

34. As a general rule, broken timber, that is, timber cut out of larger balks, should be avoided. A 10-in. stick of Swedish timber will drive better and with less risk of split-

ing than a quarter of a 20-in. balk of best Dantzic. If piles must be cut from large balks, the heart of the wood should, if possible, be left in the centre of the pile.

35. In driving sheet-piling, the piles are kept in their proper position by horizontal pieces of timber called *wales*, which are fixed to guide piles previously driven. In driving coffer-dams and similar works, the wales are seldom placed below the water-line, but this may be done with great benefit by attaching the wales to hoops dropped over the heads of the guide piles, and pushed down as low as the ground will permit. In driving into or through a hard stratum, it is desirable that the auger should precede the driving, as it will save much time, and much injury to the piles ; and in all cases where a hard-bearing stratum has to be reached at a variable depth, the boring-rod should be used to ascertain the length of pile required, as nothing is more vexatious than finding a pile a few inches too short when driven, or, on the other hand, having to cut off 5 or 6 ft. of good timber, which must be needlessly wasted.

36. Many writers have endeavored to lay down rules for calculating the effect of a given blow in sinking a pile, but investigations of this kind are of little practical value, because we can never be in possession of sufficient data to enable us to obtain even an approximate result. The effect of each blow on the pile will depend on the force of the blow, the velocity of the ram, the relative weights of the ram and the pile, the elasticity of the pile head, and the resistance offered by the ground through which the pile is passing, and as we never can ascertain the two last-named conditions with any certainty, any calculations in which they are only assumed must of necessity be mere conjectures.

37. Piles driven for temporary purposes are, at the completion of their term of service, either drawn for the value of the timber and iron shoes, or cut off at the level of the ground if they are in situations where the drawing of the piles might cause any risk to the adjacent work. When

sheet-piling has been driven round the foundations of any work, as in forming a cofferdam round the pier of a bridge, there will always be, in the event of its being drawn, the risk of the ground settling down to fill up the vacancy thereby occasioned ; but in clay or marl soils this is not the greatest danger, for the water scours out and enlarges the race thus formed, and the bottom speedily becomes broken up, nearly to the depth to which the piles were driven. As a general rule, therefore, it may be laid down, that piles in such situations should never be drawn, but should be cut off at the level of the ground, and this may be done in various ways. 1st. By common means, the men working in a diving bell, or with diving-helmets. 2d. By machinery especially constructed for the purpose. 3d. In the case of cofferdams, by cutting the piles nearly through from the inside with the adze, leaving the water on the outside of the piles to complete the operation on the removal of the strutting.

38. There are many cases, however, in which it becomes necessary to draw piles, and the modes in which this may be done are almost infinite. The common plan, where the situation will admit of it, is to make use of a balk of timber as a lever, one end of which is shackled to the head of the pile, whilst to the other end is applied such power as can most readily be obtained.

39. A very simple method of drawing piles is by means of a powerful screw, of which one end is hooked to a shackle passing round the head of the pile, whilst the other passes through a cross-head, resting firmly on temporary supports placed on each side of the pile.

40. *Cofferdams.*—A cofferdam may be described as a water-tight wall, constructed round the site of any work, for the purpose of laying dry the bottom by pumping out the water from the area thus enclosed. In some situations, this may be effected by earthern dams, by bags of clay piles on each other, or by rough caissons without top or bottom,

PANTHEON OF HADRIAN

page 276.

filled with clay, and sunk in line round the space to be enclosed ; but in the majority of cases, the method is to drive two or more rows of close piling, and to fill up the space between them with clay puddle.

41. Cofferdams are sometimes formed, in shallow water, with a single row of sheet-piling ; but this is very precarious work, as, unless the piles are fitted together with great truth, it is impossible to keep the joints close, and to prevent leakage. A single row of sheet-piling may, however, be often used with great advantage as a protection and support in front of an earthen dam, and this is a very economical and satisfactory method of proceeding where there is no depth of water.

42. Cofferdams are subject to heavy external pressure from the water round them, which would crush them in, were they not very firmly strutted. In cofferdams inclosing a small area, as, for instance, the site of the pier of a bridge, the strutting is placed from side to side, in the manner that will give the greatest facility for carrying on the work, the struts being gradually removed as the latter proceeds.

In constructing dams in front of a wharf wall, or similar work, the strutting requires to be effected in a different manner, and the plan usually adopted is to form a series of buttresses, or counterforts, at short intervals, from which the intermediate portions of the dam can be strutted with raking, horizontal struts. The strength given to these counterforts must, of course, depend on the amount of pressure to come on the dam.

43. In rivers subject to heavy freshets it is common, in constructing cofferdams, to keep the top of the dams below the flood level, as it is generally less expensive to pump out the water from the interior of the dam occasionally, than to construct and maintain a dam which should sustain the pressure of the flood waters ; and it is always advisable to provide every dam with a sluice, by mean of which the water

can be admitted, if there is any fear of injury from a sudden freshet or from any other cause. In tidal waters the operation of closing a dam is sometimes rather hazardous (unless it can be performed at low water), from the tide falling outside, without the dead water inside being able to escape sufficiently quick through the sluices to maintain an equilibrium ; and, unless the piles and puddle wall are sufficiently strong to resist this outward pressure, the work will be violently strained, and often permanently injured. When the site to be inclosed is above the level of low water, *half-tide dams* are sometimes resorted to. A half-tide dam is one which is covered and filled at every tide, and emptied by sluices at low water, the available working hours lasting from the time the bottom runs dry until the flood tide reaches the top of the dam.

44. The principal difficulties in the construction of coffer-dams may be thus briefly stated :—

1st. To obtain a firm foothold for the piles, which, in either rock or mud, is a matter of great difficulty.

2d. To prevent leakage between the surface of the ground and the bottom of the puddle.

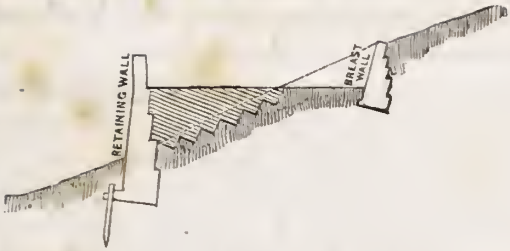
3d. To prevent leakage through the puddle wall.

4th. To keep out the bottom springs.

RETAINING WALLS.

45. The name of *retaining wall* is applied generally to all walls built to support a mass of earth in an upright or nearly upright position ; but the term is, strictly speaking, restricted to walls built to retain an artificial bank, those erected to sustain the face of the solid ground being called *breast walls.* (See fig. 8)

Fig. 8.



46. *Retaining Walls.*—Many rules have been given by different writers for calculating the thrust which a bank of earth exerts against a retaining wall, and for determining the form of wall which affords the greatest resistance with the least amount of material. The application of these rules to practice is, however, extremely difficult, because we have no means of ascertaining the exact manner in which earth acts against a wall; and they are, therefore, of little value except in determining the general principles on which the stability of these constructions depends.

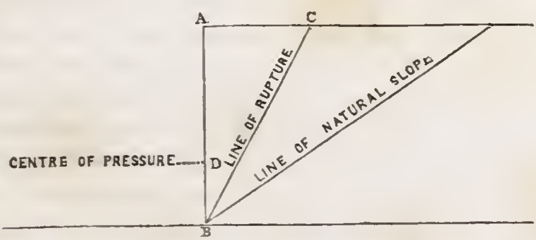
47. The calculation of the stability of a retaining wall divides itself into two parts:

1st. The thrust of the earth to be supported.

2d. The resistance of the wall.

48. Definitions (see fig. 9.)—*The line of rupture* is that along which separation takes place in case of a *slip* of

Fig. 9.



earth. The slope which the earth would assume, if left totally unsupported, is called the *natural slope*, and it has been

found that the line of rupture generally divides the angle formed by the natural slope and the back of the wall into nearly equal parts.

The *centre of pressure* is that point in the back of the wall above and below which there is an equal amount of pressure; and this has been found by experiment and calculation to be at two-thirds of the vertical height of the wall from its top.

The wall is assumed to be a solid mass, incapable of sliding forward, and giving way only by turning over on its front edge as a fulcrum. In the annexed diagrams the foundations of the walls have, in all cases, been omitted, to simplify the subject as much as possible. The term *slope* in the following investigation is used as synonymous with the expression *line of rupture.*

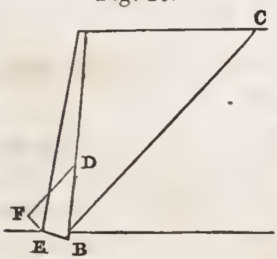
49. *Amount and Direction of the Thrust.*—There are two ways in which this may be calculated :—1st, By considering the earth as a solid mass sliding down an inclined plane, all slipping between the earth and the back of the wall being prevented by friction. This gives the *minimum* thrust of the earth. 2nd, By assuming the particles of earth to have so little cohesion, that there is no friction either on the slope or against the back of the wall. This method of calculation gives the *maximum* thrust.

The real thrust of any bank will probably be somewhere between the two, depending on a variety of conditions which it is impossible to reduce to calculation ; for, although we may by actual experiments with sand, gravel, and earths of different kinds, obtain data whence to calculate the thrust exerted by them in a perfectly dry state, another point must be attended to when we attempt to reduce these results to practice, viz., the action of water, which, by destroying the cohesion of the particles of earth, brings the mass of material behind the wall into a semi-fluid state, rendering its action more or less similar to that of a fluid according to the degree of saturation.

The tendency to slip will also very greatly depend on the manner in which the material is *filled* against the wall. If the ground be *benched out* (see fig. 8,) and the earth well punned in layers inclined *from* the wall, the pressure will be very trifling, provided only that attention be paid to surface and back drainage. If, on the other hand, the bank be tipped in the usual manner in layers sloping *towards* the wall, the full pressure of the earth will be exerted against it, and it must be made of corresponding strength.

50. *Calculation of Minimum Thrust.*—The weight of the prism of earth represented by the triangle A B C, fig. 9, will be directly as the breadth AC, the height being constant; and the inclination of B C remaining constant, but the height varying, the weight will be as the square of the height. If, therefore, we call the weight of the prism A B C, W, the breadth AC, b, the height AB, h, and the specific gravity of the earth, s, we shall have $W = \frac{b\,h\,s}{2}$. If we call the thrust of W in the direction of the slope W′, then (neglecting friction,) on the principle of the inclined plane, W will be to W′ as the length of the incline is to its height; or, calling the length B C, l, then

Fig. 10.



$$l : h :: W : W' = \frac{h\,W}{l} = \frac{b\,h^2\,s^*}{2\,l}.$$

* The value of W′ here given will increase with the length of A C in a constantly decreasing ratio, never exceeding $\frac{h^2 s}{2}$ supposing the back of the wall to be upright. But in practice the friction must always be taken into consideration; and, as this increases directly as A C, there will be a limit at which the thrust and the resistance balance each other, this limit being the natural slope; and, as the thrust and the resistance increase with the length of A C in different ratios, there will be a point at which the effective thrust is greatest, or, in other words, a slope of maximum thrust which determines the position of the line of rupture.

The effect of the weight of the prism A B C to overturn the wall will be as W′ multiplied by the leverage E F, fig. 10, found by letting fall the perpendicular E F, from the front edge of the wall, upon D F, drawn through the centre of pressure in a direction parallel to the slope. When D F passes through E, then E F = O, and the thrust has no tendency to overturn the wall; and when D F falls within the base of the wall, E F becomes a negative quantity, the thrust increasing its stability. Calling the overturning thrust **T**, we have

$$T = W' \times EF = \frac{b\,h^2 s + EF,}{2\,l}$$

the value of E F* depending on the inclination of the slope, and the width of the base of the wall.

51. *Calculation of Maximum Thrust.*—If we consider the moving mass to slide freely down the slope, and the friction between the earth and the back of the wall to be so slight as to be inappreciable, then the prism A B C will act as a wedge, with a pressure perpendicular to the back of the wall, which will be the same whatever the inclination of B C, the height and inclination of the back of the wall being constant, and as the square of the height where the height varies, the pressure being the least when the back of the wall is vertical; for calling the pressure P, and drawing A I, fig. 11, perpendicular to B C, we have, on the principle of the wedge,

$$AI : AB :: W' : P = \frac{W' \times AB}{AI} = \frac{b\,h^2 s \times AB}{2\,l \times AI}.$$

and by construction $b\,h = l\,AI$, as they are each equal to

---

$$* \; EF = \frac{h}{l} \times \left(\frac{b}{3} - EB\right) \text{ and}$$

$$T = W' \times EF = \frac{b\;b^2\;s}{2l} \times \frac{h}{l}\left(\frac{b}{3} - EB\right) - \frac{b\;h^3\;s}{2l^2} \times \left(\frac{b}{3} - EB\right)$$

twice the area of triangle A B C ; therefore, by substitution,

$$P = \frac{l\,A\,I\,h\,s \times A\,B}{2\,l\,A\,I} = \frac{h\,s \times A\,B}{2}.$$

The effect of the prism A B C to overturn the wall will be P multiplied by the leverage E F*, which will be found by drawing D F, fig 13, at right angles to the back of the wall

Fig. 11.

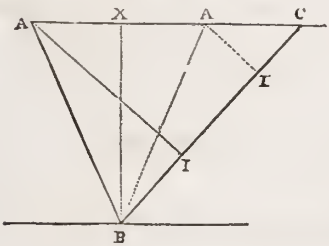
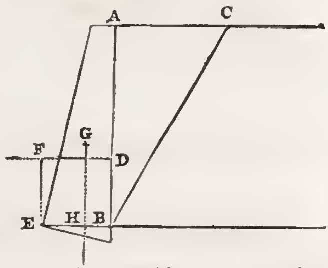


Fig. 12.



through the centre of pressure, and making E F perpendicular to it ; then calling the overturning thrust, as before, T,

$$T = P \times E\,F = \frac{A\,B \times h\,s \times E\,F}{2}$$

When D F passes through E, then E F = 0, and the thrust has no tendency to overturn the wall ; and, if D F falls within the base, the thrust will *increase* its stability. When the back of the wall is vertical, then

$$A\,B = h \text{ and } E\,F = \frac{h}{3} \text{ and } T = \frac{h^3 s}{6}.$$

---

* Calling the angle X A B = θ

$$E\,F = \frac{A\,B}{3} \pm \frac{E\,B.\,A\,X}{A\,B} = \frac{h}{3} \operatorname{cosec} \theta \pm E\,B \cos.\,\theta$$

$$\text{And } T = P \times E\,F = \frac{A\,B.\,h\,s}{2} \times \left(\frac{A\,B}{3} \pm \frac{E\,B.\,A\,X}{A\,B} \right) =$$

$$\frac{h\,s}{2} \times \left(\frac{A\,B^2}{3} \pm E\,B.\,A\,X \right)$$

The positive sign is to be used when the back of the wall leans backwards ; the negative, when it leans forwards.

52. These results show that, where the friction of the earth against the slope and the back of the wall is destroyed by the filtration of water, the action of the earth will be precisely similar to that of a column of water of the height of the wall. The pressure upon the side of any vessel is the half of the pressure that would take place upon the bottom if of the same area. Now, calling the specific gravity of the water s, the pressure upon the bottom, supposing its length to be A B, would be $h s$ A B ; therefore the pressure upon the side will be

$$\frac{h s \, AB}{2}; \text{ and } T = P \times EF = \frac{h s \, AB.EF}{2}.$$

And, where the back of the wall is vertical, then

$$AB = h \text{ and } EF = \frac{h}{3} \text{ as above. Therefore}$$

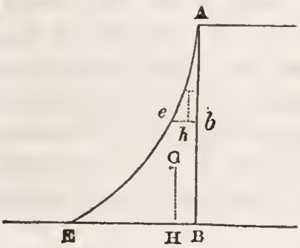
$$P \frac{h^2 s}{2} \text{ and } T = \frac{h^2 s}{2} \times \frac{h}{3} = \frac{h^3 s}{6};$$

which results are precisely the same as those arrived at above.

53. *Resistance of the Wall.*—Considering the wall as a solid mass, the effect of its weight to resist an overturning thrust will be directly as the horizontal distance E H from its front edge to a vertical line drawn through G, the centre of gravity of the wall, fig. 13 ; or, calling the resistance R, and the weight of the wall w, then $R = w \times EH$. E H will be directly as E B, the proportions of the wall being constant ; therefore a wall of triangular section will afford more resistance than a rectangular one of equal sectional area, the base of a triangle being twice that of a rectangle of equal height and area.

If the wall be built with a curved concave batter, fig. 14, E H will be still greater than in the case of a triangular wall of equal sectional area ; and, if the wall were one solid

Fig. 13.



mass incapable of fracture, this form would offer more resistance than the triangular. But, as this is not the case, we may consider any portion of the wall cut off from the bottom by a level line to be a distinct wall resting upon the lower part as a foundation. Imagine A *e* *b* to be a complete wall capable of turning upon *e* as a fulcrum. The resistance would be considerably less than that of the corresponding portion of a triangular wall. In the case of a triangular wall, the proportions of the resistance to the thrust will be the same throughout its height. In the case of a rectangular one, the resistance will bear a greater proportion to the thrust, the greater the distance from the bottom. In the case of a wall with a concave curved batter, the reverse of this takes place.

The value of E H will be greatest when E H = E B, the wall will be then exactly balanced on H ; but in practice this limit should never be reached, for fear the wall should become crippled by depending on the earth for support. The value of E H will be least when H coincides with E, which opposite limit also is never reached in practice—for obvious reasons—as the wall would in this case overhang its base, and be on the point of falling forward.

54. The increased leverage is not the only advantage gained by the triangular form of wall. In the foregoing investigation, we have considered the wall as a solid mass turning on its front edge. Now, practically, the difficulty is not so much to keep the wall from overturning as to prevent the courses from sliding on each other.

In an upright wall, built in horizontal courses, the chief resistance to sliding arises from the adhesion of the mortar ; but, if the wall be built with a sloping or *battering* face, the beds of the courses being inclined to the horizon, the resist-

ance to the thrust of the bank is increased in proportion to the tendency of the courses to slide down towards the bank; thus rendering the adhesion of the mortar merely an additional security. The importance of making the resistance independent of the adhesion of the mortar is obviously very great, as it would otherwise be necessary to delay backing up a wall until the mortar were thoroughly set, which might require several months.

55. The exact determination of the thrust which will be exerted against a wall of given height is not possible in practice; because the thrust depends on the cohesion of the earth, the dryness of the material, the mode of backing up the wall, and other conditions which we have no means of ascertaining. Experience has, however, shown that the base of the wall should not be less than one-fourth, and the batter or slope not less than one-sixth of the vertical height, wherever the case is at all doubtful.

56. The results of the above investigation are illustrated in figures 14, 15, 16, 17, and 18, which show the relative

Fig. 14.

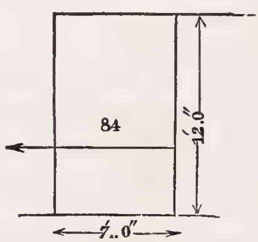
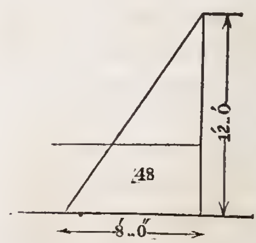


Fig. 15.



sectional areas of walls of different shapes, that would be required to resist the pressure of a bank of earth 12 feet high.

Fig. 16.

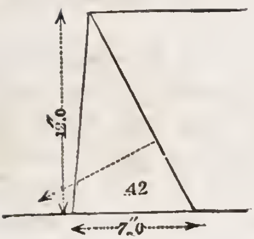


Fig. 17.

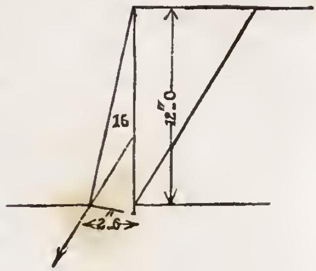
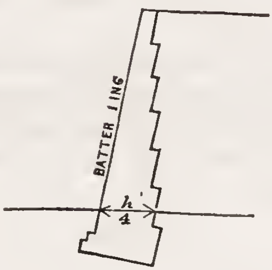


Fig. 18.



The first three examples are calculated to resist the maxi mum, and the fourth, the minimum, thrust ; whilst the last figure shows the modified form usually adopted in practice.

57. It is sometimes necessary in soft ground to protect the *toe* or front edge of a retaining wall with sheet piling, to prevent it from being forced forward ; this is shown in fig. 8.

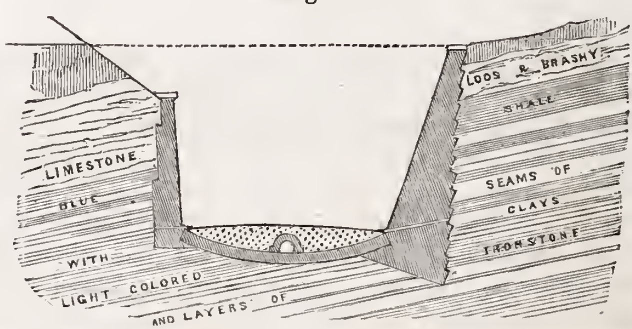
58. *Counterforts.*—Retaining walls are often built with counterforts, or buttresses, at short distances apart, which allow of the general section of the wall being made lighter than would otherwise be the case. The principle on which these counterforts are generally built is, however, very defective, as they are usually placed *behind* the wall, which frequently becomes torn from them by the pressure of the earth. The strength of any retaining wall would, however, be greatly increased were it built as a series of arches, abut

ting on long and thin buttresses ; but the loss of space that would attend this mode of construction has effectually prevented its adoption except in a few instances.

59. *Breast Walls.*—Where the ground to be supported is firm, and the strata are horizontal, the office of a breast wall is more to protect, than to sustain the earth. It should be borne in mind that a trifling force, skilfully applied to unbroken ground, will keep in its place a mass of material which, if once allowed to move, would crush a heavy wall ; and, therefore, great care should be taken not to expose the newly opened ground to the influence of air and wet for a moment longer than is requisite for sound work, and to avoid leaving the smallest space for motion between the back of the wall and the ground.

60. The strength of a breast wall must be proportionately increased when the strata to be supported incline *towards* the wall, as in fig. 19 : where they incline from it, the wall need be little more than a thin facing to protect the ground from disintegration.

Fig 19.



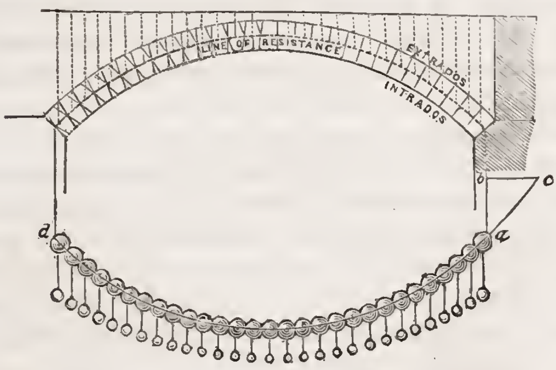
61. The preservation of the natural drainage is one of the most important points to be attended to in the erection of breast walls, as upon this their stability in a great measure depends. No rule can be given for the best manner of doing this ; it must be a matter for attentive consideration in each particular case.

ARCHES.

62. An arch in perfect equilibrium may be considered as a slightly elastic curved beam, every part of which is in a state of compression, the pressure arising from the weight of the arch and its superincumbent load being transmitted to the abutments on which it rests in a curved line called the *curve of equilibrium*, passing through the thickness of the arch.

63. The wedge-shaped stones of which a stone arch is composed are called the *voussoirs*. The upper surface of an arch is called its *extrados*, and the lower surface its *intrados* or *soffit* (see fig. 20). Theoretically, a stone arch might

Fig. 20.



give way by the sliding of the voussoirs on each other; but in practice the friction of the material and the adhesion of the mortar is sufficient to prevent this, and failure takes place in the case of an overloaded arch by the voussoirs turning on their edges.

64. The curve of equilibrium will vary with the rise and span of the arch, the depth of the arch stones, and the distribution of the load, but it will always have this property, namely, that the horizontal thrust will be the same at every part of it. In order that an arch may be in perfect equili-

brium, its curvature should coincide with that of the curve of equal horizontal thrust; if, from being improperly designed or unequally loaded, this latter curve approaches either the intrados or the extrados, the voussoirs will be liable to fracture from the pressure being thrown on a very small bearing surface; and if it be not contained within the thickness of the arch, failure will take place by the joints opening, and the voussoirs turning on their edges.

65. The manner in which the curve of equilibrium is affected by any alteration in the load placed upon an arch may readily be seen by making an experimental equilibrated arch with convex voussoirs, as shown in fig. 20. When bearing its own weight only, the points of contact of the voussoirs will lie wholly in the centre of the thickness of the arch; when loaded at the crown, the points of contact will approach the extrados at the crown, and the intrados at the haunches; and, if loaded at the haunches, the reverse effect will take place.

66. If a chain be suspended at two points, and allowed to hang freely between them, the curve it takes is the curve of equilibrium of an arch of the same span and length on soffit, in which the weights of the voussoirs correspond to the weights of the links of the chain, and would be precisely the same as that marked out by the points of contact of the curved voussoirs of an experimental arch of the same dimensions built as above described.

67. In designing an arch, two methods of proceeding present themselves: we may either confine the load to the weight of the arch itself or nearly so, and suit the shape of the arch to a given curve of equilibrium, or we may design the arch as taste or circumstances may dictate, and load it until the line of resistance coincides with the curve thus determined upon.

The Gothic vaults of the middle ages were, in a great measure, constructed on the first of these methods, being in many cases only a few inches in thickness, and the curvature

of the main ribs coinciding very nearly with their curves of equal horizontal thrust. We have no means of ascertaining whether this was the result of calculation or experiment; probably the latter, but the principle was evidently understood.

At the present day, the requirements of modern bridge building often leave the architect little room for choice in the proportions of his arches, or the height and inclinations of the roadway they are to carry; and it becomes necessary to calculate with care the proportion of the load which each part of the arch must sustain, in order that the curve of equilibrium may coincide with the curvature of the arch.

68. The formulæ for calculating the equilibration of an arch are of too intricate a nature to be introduced in these pages; but the principles on which they depend are very simple.

Let it be required to construct a stone arch of a given curvature to support a level roadway, as shown in fig. 20, and to find the weight with which each course of voussoirs must be loaded to bring the arch into equilibrium.

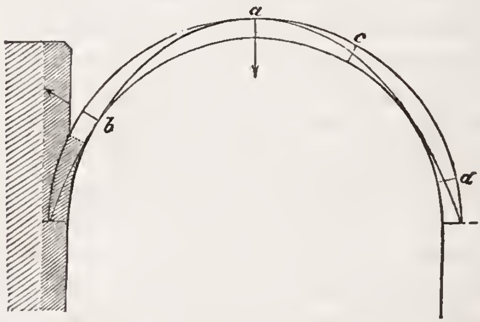
Draw the centre line of the arch to a tolerably large scale in an inverted position on a vertical plane, as a drawing board, for instance, and from its springing points *a*, *d*, suspend a fine silk thread of the length of this centre line strung with balls of diameter and weight corresponding to the thickness and weight of the voussoirs of the arch; then, from the centre of each ball suspend such a weight as will bring the thread to the curve marked on the board, and these weights will represent the load which must be placed over the centre of gravity of each of the voussoirs, as shown by the dotted lines, in order that the arch may be in equilibrium.

To find what will be the thrust at the abutments, or at any point in the arch, draw *a c*, touching the curve, the vertical line *a b* of any convenient length, and the horizontal line *b c*, then the lengths of the lines *a c*, *a b*, and *b c*, will be

respectively as the thrust of the arch at *a*, in the direction *a c*, and the vertical pressure and horizontal thrust into which it is resolved ; and the weight of that part of the arch between its centre and the point *a*, which is represented by *a b*, being known, the other forces are readily calculated from it.

69. When the form of an arch does not exactly coincide with its curve of equal horizontal thrust, there will always be some minimum thickness necessary to contain this curve, and to insure the stability of the arch. In a semicircular, fig. 21, whose thickness is one-ninth of its radius, the line of equal horizontal thrust just touches the extrados at the crown, and the intrados at the haunches, pointing out the places where failure would take place with a less thickness or an unequal load, by the voussoirs turning on their edges. Those arches which differ most from their curves of equal horizontal thrust are semicircles and semi-ellipses, which have a tendency to descend at their crowns and to rise at their haunches, unless

Fig. 21.



they are well *backed up*. Pointed arches have a tendency to *rise* at the crown ; and, to prevent this, the cross springers of the ribbed vaults of the middle ages were often made of a semicircular profile, their flatness at the crown being concealed by the bosses at their intersections.

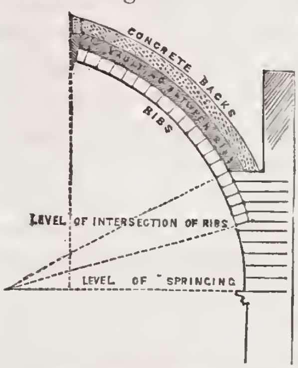
70. If the experiment be tried of equilibrating, in the manner above described, a suspended semicircular or semi-

elliptical arch, it will be found to be practically impossible, as the weight required for that purpose becomes infinite at the springing. This difficulty does not exist in practice, for that part of an arch which lies beyond the plane of the face of the abutment in reality forms a part of the abutment itself (fig. 21).

The Gothic architects well understood this, and in their vaulted roofs built this portion in horizontal courses as part of the side walls (fig. 22), commencing the real arch at a point considerably above the spinging.

71. The depth of the voussoirs in any arch must be sufficient to contain the curve of equilibrium under the greatest load to which it can be exposed; and, as the pressure on the arch stones increases from the crown to the springing, their depth should be increased in the same proportion. Each joint of the voussoirs should be at right angles to a tangent to the curve of equilibrium at the point through which it passes.

Fig. 22.*



72. *Brick Arches.*—In building arches with bricks of the common shape, which are of the same thickness throughout their length, a difficulty arises from the thickness of the mortar joints at the extrados being greater than at the intrados, thus causing settlement and sometimes total failure. To obviate this difficulty, it is usual to build brick arches in separate rings of the thickness of half a brick, having no connection with each other beyond the adhesion of the mortar or cement, except an occasional course of headings where the joints of two rings happen to coincide. There is, how-

* This diagram is slightly altered from one of the illustrations to Professor Willis's paper "On the Construction of the Vaults of the Middle Ages," in the Transactions of the Royal Institute of British Architects, Vol. I., Part 2.

ever, a strong objection to this plan, viz., that, if the curve of equal horizontal thrust do not coincide with the curvature of the arch, the line of pressure will cross the rings, and cause them to separate from each other.

73. The preferable plan will be, therefore, to bond the brick-work throughout the whole thickness of the arch, using either cement or hard-setting mortar, which will render the thickness of the joints of comparatively little importance.

Cement, however, is not so well suited for this purpose as the hard setting mortars made from the Lias limes, because it sets before the work can be completed ; and in case of any settlement, however trifling, taking place on the striking of the centres, the work becomes crippled. It is therefore preferable to use some hard setting mortar, which does not, however, set so quickly as cement, thus allowing the arch to adjust itself to its load, or, in technical language, to *take its bearing*, before the mortar becomes perfectly hard.

72. We have in the preceding remarks considered an equilibrated arch as a curved beam, every part of which is in a state of compression ; and, in an arch composed of stone voussoirs, this is practically the case.

We may, however, by the employment of other materials, as cast iron and timber, construct arches whose forms differ very materially from their curves of equal horizontal thrust.

Thus the semicircular arch (fig. 21,) which, if built of stone voussoirs small in proportion to the span of the arch, would fail by the opening of the joints at a and b, might be safely constructed with cast-iron ribs, with the joints placed at c and d, the metal at the points a and b being exposed to a cross-strain precisely similar to that of a horizontal beam loaded in the centre.

73 Laminated arched beams, formed of planks bent round a mould to the required curve and bolted together, have been extensively used in railway bridges of large span during the last ten years, and from their comparative elasticity, and the resistance they offer to both tension and com

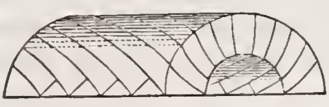
pression, are very well adapted to structures of this kind, which have to sustain very heavy loads passing with great rapidity over them.

It is to be regretted, however, that the perishable nature of the material does not warrant their long duration, notwithstanding every precaution that can be taken for the preservation of the timber.

74. *Skew Arches.*—In ordinary cases the plan of an arch is rectangular, the faces of the abutments being at right angles to the fronts ; but of late years the necessity which has arisen on railway works of carrying communications across each other without regard to the angle of their intersection, has led to the construction of oblique or *skew* arches.

75. In an ordinary rectangular arch each course is parallel to the abutments, and the inclination of any bed joint with the horizon will be the same at every part of it. In a skew arch it is not possible to lay the courses parallel to the abutments, for, were this done, the thrust being at right angles to the direction of the courses, a great portion of the arch on each side would have nothing to keep it from falling. In order to bring the thrust into the right direction, the courses must therefore be laid as nearly as possible at right angles to the fronts of the arch (see fig. 23,) and at an angle with the abutments ; and it is this which produces the peculiarity of the skew arch. The two ends of any course will then be at different heights, and the inclination of each bed joint with the horizon will increase from the springing to the crown, causing the beds to be *winding* surfaces instead of a series of planes, as in a rectangular arch. The variation in the inclination of the bed joints is called the *twist* of the beds, and leads to many difficult problems in stone-cutting, the consideration of which

Fig. 23.



would be unsuited to the elementary character of this little work.

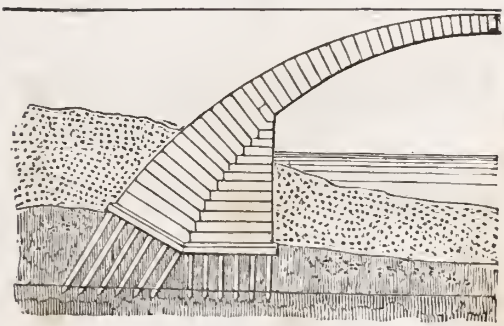
76. *Centering.*—The *centering* of an arch is the temporary framework which supports it during its erection, and is formed of a number of ribs or *centres*, on which are placed the planks or *laggings* on which the work is built.

77. In designing centres, there are three essential points to be kept in view. 1st, that there should be sufficient strength to prevent any settlement or change of form during the erection of the arch. 2d, that means should be provided for *easing* or lowering the centre gradually from under any part of the arch. 3d, that, as the construction of centres generally involves the use of a large quantity of timber merely for a temporary purpose, all unnecessary injury to it should be avoided, in order that its value for subsequent use may be as little diminished as possible.

78. Where the circumstances of the case do not admit of piles or other supports being placed between the piers, it becomes necessary to construct a trussed framing resting on the piers, and of sufficient strength to support the weight of the arch. The tendency of this form of centre to rise at the crown, from the great pressure thrown upon the haunches during the erection of the arch, renders it necessary to weight the crowns with blocks of stone until it is nearly completed. Centres of this kind are always costly, and afford little facilities for easing.

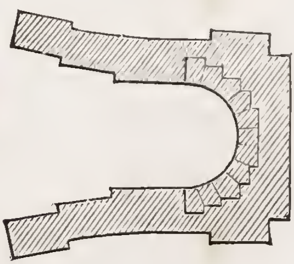
79. *Abutments.*—The tendency of any arch to overturn its abutments, or to destroy them by causing the courses to slide over each other, may be counteracted in three ways. 1st, the arch may be continued through the abutment until it rests on solid foundation, as in fig. 24. 2d, by building the abutments so as to form a horizontal arch, the thrust

Fig. 24.



being thrown on the wing walls, which act as buttresses (fig. 24.) 3d, where neither of these expedients

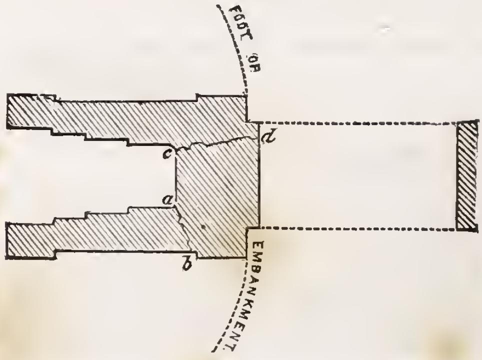
Fig. 25.



is practicable, by joggling the courses together with bed-dowel joggles, so as to render the whole abutment one solid mass.

80. *Wing Walls.*—Where the wing walls of a bridge are built as shown in fig. 26, the pressure of the earth will always have a tendency to fracture them at their junction

Fig. 26.



with the abutments, as shown by the lines *a b, c d.* Equal strength with the same amount of material will be obtained by building a number of thin longitudinal and cross walls, as shown in fig. 27, by which means, the earth being kept from

Fig. 27.

the back of the walls, there is no tendency to failure of this kind.

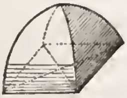
81. *Vaulting.*—The ordinary forms of vaults may be classed under three heads, viz., *cylindrical*, *coved*, and *groined*

A *cylindrical* vault is simply a semicircular arch, the ends of which are closed by upright walls, as shown in fig. 28.

When a vault springs from all the sides of its plan, as in fig. 29, it is said to be *coved.* When two cylindrical vaults in-

Fig. 28.

Fig. 29.

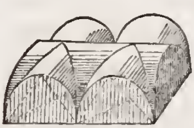


tersect each other, as in fig. 30, the intersections of the vaulting surfaces are called *groins*, and the vault is said to be *groined.*

82. In the Roman style of architecture, and in all common vaulting, the vaulted surfaces of the several compartments are portions of a continuous cylindrical surface, and the profile of a groin is simply an oblique section of a semi-cylinder.

83. Gothic ribbed vaulting is, however, constructed on a totally different principle. It consists of a framework of light stone ribs supporting thin panels, whence this mode of construction has obtained the name of *rib and pannel* vaulting. The curvature of the diagonal ribs or cross springers, and of the intermediate ribs, is not governed in any way by the form of the transverse section of the vault, and in this consists the peculiarity of ribbed vaulting. This will be understood by a comparison of figs. 30 and 31.

Fig. 30.



Roman vaulting.

Fig. 31.

Gothic vaulting.

84. Domes are vaults on a circular plan. The equilibrium of a dome depends on the same conditions as that of a common arch, but with this difference, that, although a dome may give way by the weight of the crown forcing out the haunches, failure by the weight of the haunches squeez-

ing up the crown is impossible, on account of the support the voussoirs of each course receive from each other.

MASONRY—BRICKWORK—BOND.

85. The term *masonry* is sometimes applied generally to all cemented constructions, whether built of brick or stone; but generally the use of the term is confined exclusively to stone-work.

86. There are many kinds of masonry, each of which is known by some technical term expressive of the manner in which the stone is worked; but they may all be divided under three heads.

1st. Rubble work (fig. 32,) in which the stones are used without being squared.

2nd. Coursed work (fig. 33,) in which the stones are squared, more or less, sorted into sizes, and ranged in courses.

Fig. 32.

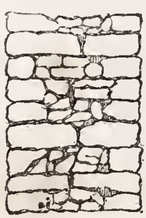


Fig. 33.

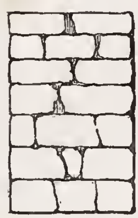
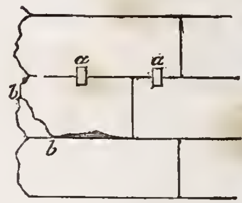


Fig. 34.



3d. Ashlar work* (fig. 34), in which each stone is squared and dressed to given dimensions.

87. Different kinds of masonry are often united. Thus a wall may be built with ashlar facing and rubble backing; and there are many gradations from one class of masonry to another, as *coursed rubble*, which is an intermediate step between rubble work and coursed work.

88. In ashlar masonry, the stability of the work is

* In London, the term "ashlar" is commonly applied to a thin facing of stone placed in front of brickwork.

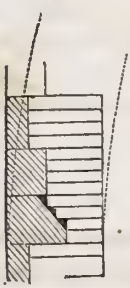
independent, in ordinary cases, of the adhesion of the mortar. Rubble work, on the contrary, depends for support in a great measure upon it.

89. In dressing the beds of ashlar work, care must be taken not to work them hollow, so as to throw the pressure upon the edges of the stones, as this leads to unsightly fractures, as *b b*, fig. 34.

90. Where there is a tendency of the courses to slide on each other from any lateral pressure, it may be prevented by bed-dowel joggles, as shown at *a a*, fig 34.

91. Where the facing and the backing of a wall do not contain the same number of courses, as in the case of a brick wall with stone facings (fig. 35) the work will be liable to settle on the inside, as shown by the dotted lines, from the greater number of mortar joints. The only way of preventing this is to set the backing in cement, or some hard and quick-setting mortar.

Fig. 35.



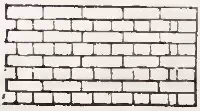
92. In facing brickwork with stone ashlar, the stones should be all truly squared, and worked to sizes that will bond with the brickwork. If this be neglected, there will be numerous vacuities in the thickness of the wall (see fig. 35), and the facing and backing will have a tendency to separate.

93. *Bond*, in masonry, consists in the placing of the stones in such relative positions that no joint in any course shall be in the same plane with any other joint in the course immediately above or below it. This is called *breaking joint*.

94. Stones placed lengthwise in any work are called *stretchers*, and those placed in a contrary direction are

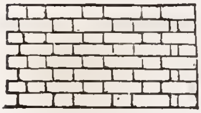
called *headers.* When a header extends throughout the whole thickness of a wall, it is called a *through.*

Fig. 36.



English Bond.

Fig. 37.



Flemish Bond.

95. There are two kinds of bond made use of by bricklayers, called respectively *English bond* and *Flemish bond.* In the first the courses are laid alternately with headers and stretchers (fig. 36) ; in the second, the headers and stretchers alternate in the same course (fig. 37). This is considered to have the neatest appearance : but, as the number of headers required is fewer than in English bond, there is not so much lateral tie, and on this account it is considered to be much inferior to it in strength. A common practice, which cannot be too much reprobated, is that of building brick walls with two qualities of bricks, without any bond between them, the headers of the facing bricks being cut in two to save the better material, thus leaving an upright joint between the facing and backing.

95. In building upright walls, which have to sustain a vertical pressure, three leading principles must be kept in view.

1. Uniformity of construction throughout the whole thickness.
2. The bonding of the work together.
3. The proper distribution of the load.

96. *Uniformity of Construction.*—We have already spoken of the danger arising from the backing of a wall containing more compressible material than the facing ; but it cannot be too often repeated, that in all building operations it is not the *amount*, but *irregularity* of settlement which is so dangerous. Thus a rubble wall, with proper care, may be carried up to a great height, and bear safely the weight of the floors and roof of a large building, whilst a wall built of bricks

and mortar, and faced with dressed ashlar, will, under similar circumstances, be fractured from top to bottom, from the difference in settlement of the facing and backing.

It is a common but vicious practice to build the ends of joists and other timbers into the walls, and to rest the superincumbent work upon them. This is liable to lead tc settlements from the shrinking of the timber, and should always be guarded against by leaving proper recesses for the ends of the timbers, so that the strength of the masonry or brick-work shall be quite independent of any support from them.

97. *Bond.*—In addition to the bonding together of the materials above described, a further security against irregular settlement is usually provided for brick walls, in the shape of ties of timber, called *bond*, which are cut of the depth and thickness of a brick, and built into the work. There is, however, a great objection to the use of timber in the construction of a wall, as it shrinks away from the rest of the work, and often endangers its stability by rotting.

98. Instead of bond timbers, hoop-iron bond is now very generally used. This is formed of iron hooping, tarred, to protect the iron from contact with the mortar, and laid in the thickness of the mortar joints. This forms a very perfect longitudinal tie, and has all the advantages, with none of the disadvantages, of bond timbers.

99. *Distribution of the Load.*—It is always advisable, when a heavy load has to be supported on a few points, as in the case of a larger floor resting on girders, to bring the weight as nearly as possible on the centre of the wall, and to distribute it over a large bearing surface, by stone bond ing through its whole thickness ; this arrangement is shown in figures 38 and 39.

Fig. 38.

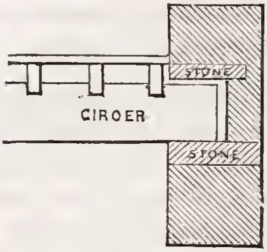


Fig. 39.

100. It is of importance in designing buildings to arrange the apertures for doors, windows, &c., in the different floors, so that openings shall be over openings, and piers over piers; if this be not attended to, it is scarcely possible to prevent settlements. In addition to this, as the pressure on the foundations will be greatest under the piers, it is desirable to connect these with inverted arches, by which means the weight is distributed equally over the whole surface of the foundations.

101. All openings in walls for doors, windows, gate-ways, &c., should be arched over throughout the whole thickness of the walls in which they occur; and wooden lintels and bressummers should only be introduced as ties to counteract the thrust of the arches, and as attachments for the internal finishings.

102. Bressummers of cast iron are often used for supporting the walls of houses over large openings, as in the case of shop fronts; but they have the disadvantage of being liable to be cracked, in case of fire, if water is thrown on them whilst in a heated state, which renders their use very objectionable, as no dependence can be placed upon them after having been suddenly cooled in this manner, even if they do not actually break at the time.

PARTITIONS.

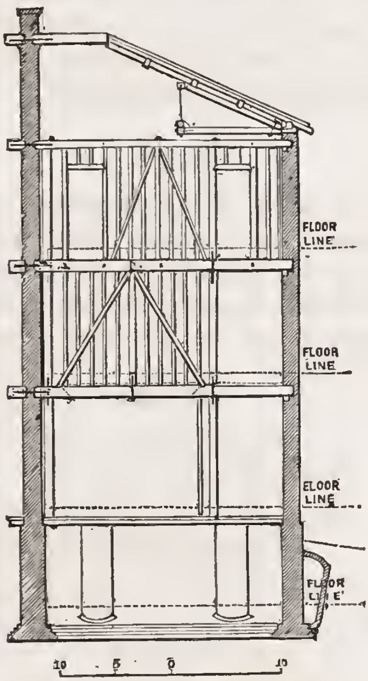
103. The partitions forming the interior divisions of a building may be either solid walling of brick or stone, or

they may be constructed entirely of timber, or they may be frames of timber filled in with masonry or brick-work.

It will always be best, both for durability and security against fire, to make the partitions of solid walling; but this is not always practicable, and, in the erection of dwelling houses, they are for the most part made of timber.

The principles to be kept in view in the construction of framed timber partitions are very simple. Care must be taken to avoid any settlement from cross strain, and they should not in any way depend for support upon subordinate parts of the construction, but should form a portion of the main

Fig. 40.



carcase of the building, and be quite independent of the floors, which should not support, but should be supported by them.

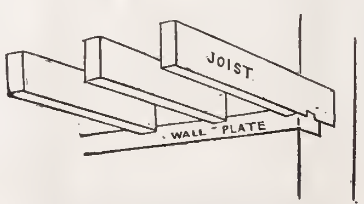
Where a partition extends through two or more stories of a building, it should be as much as possible a continuous piece of framing, with strong sills at proper heights to support the floor joists.

Where openings occur, as for folding doors, or where a partition rests on the ends of the sill only, it should be strongly trussed, so that it is as incapable of settlement as the walls themselves. From want of attention to these points, we frequently see in dwelling-houses floors which have sunk into curved lines, doors out of square, cracked ceilings and broken cornices, and gutters that only serve to conduct the roof water to the interior of the building, to the injury of ceilings and walls, and the great discomfort of its inmates. The above remarks will be better understood by a study of fig. 40, which is an example of a framed partition extending through three stories of a dwelling house.

FLOORS.

104. The assemblage of timbers forming any *naked flooring* may be either *single* or *double*. Single flooring is formed with joists reaching from wall to wall, where they rest on *plates* of timber built into the brick-work, as in fig. 41. The floor boards are nailed over the upper edges of the joists,

Fig. 41.

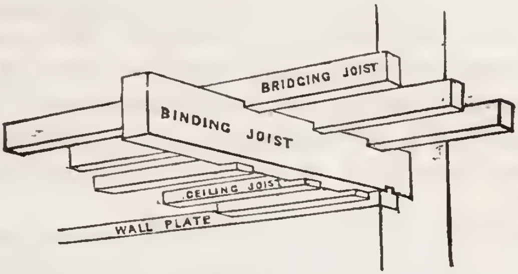


Single flooring.

whose lower edges receive the lathing and plastering of the ceilings. Double floors are constructed with stout *binding joists*, a few feet apart, reaching from wall to wall, and sup

porting *ceiling joists* which carry the ceiling; and *bridging joists*, on which are nailed the floor boards (fig. 42.)

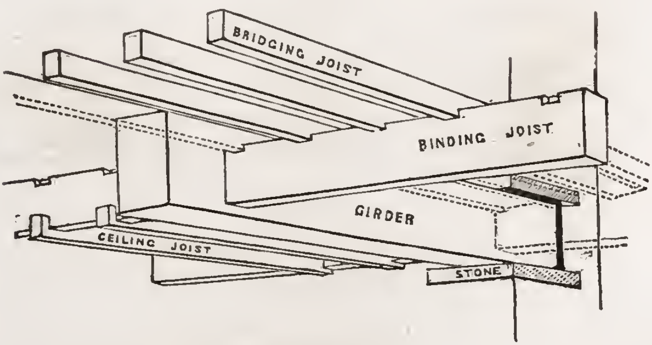
Fig. 42.



Double flooring.

In *double-framed flooring*, the binders, instead of resting in the walls, are supported on *girders*, as shown in fig. 43. Single flooring is, in many respects, inferior to double floor-

Fig. 43.



Double-framed flooring.

ing, being liable to *sag*, or deflect, so as to make the floor concave; and the vibration of the joists occasions injury to the ceilings, and also shakes the walls. In double flooring the stiffness of the binders and girders prevents both deflection and vibration, and the floors and ceilings *hold their lines*, that is, retain their intended form much better than in single flooring.

105. The joists in a single floor are usually laid on a plate built into the wall, as shown in fig. 41 ; it is, however, preferable to rest the plate on projecting corbels, which prevents the wall being crippled in any way, by the insertion of the joists. The plates of basement floors are best supported on small piers carried up from the footings. This is an important point to be attended to, as the introduction of timber into a wall is nowhere likely to be productive of such injurious effects as at the foundations, where, from damp and imperfect ventilation, all wood-work is liable to speedy decay.

The ends of all girders should rest in recesses, formed as shown in figs. 38 and 39, and with a space for the free circulation of air round the timber, which is one of the best preventives of decay.

The manner in which ceiling joists and bridging joists are framed to the binders, and these latter tenoned into the girders, is shown in figs. 44, 45, 46, and 47.

Fig. 44.

Fig. 45.

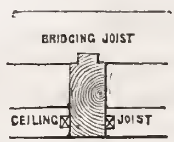


Fig. 46.

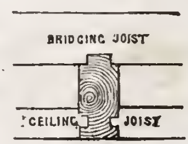
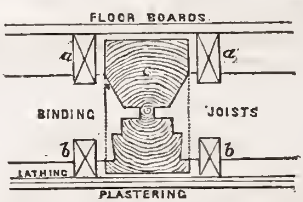


Fig. 47.



a a, bridging joists ; *b b*, ceiling joists ; *c*, girder

106. Fire-proof floors are usually constructed with iron girders a short distance apart, which serve as abutments for a series of brick arches, on which either a wooden or plaster floor may be laid (see fig. 48).

Fig. 48.

107. Of late years many terraces and flat roofs have been constructed with two or more courses of plain tiles, set in cement, and breaking joint with each other, supported at short intervals by cast-iron bearers, as shown in fig. 49.

Fig. 49.

This mode of construction, although appearing very slight, possesses great strength, and is now very much used in and about London, and in some portions of the United States.

ROOFING.

108. In roofs of the ordinary construction, the roof covering is laid upon *rafters* supported by horizontal *purlins*, which rest on upright *trusses* or frames of timber, placed on the walls at regular distances from each other. Upon the framing of the trusses depends the stability of the roof, the arrangement of the rafters and purlins being subordinate matters of detail. The timbering of a roof may be compared to that of a double-framed floor, the trusses of the former corresponding to the girders of the latter, the purlins to the binders, and the rafters to the joists.

Timber roofs may be divided under two heads—

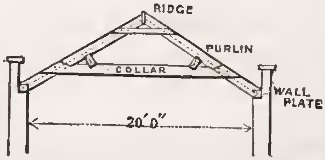
1st. Those which exert merely a vertical pressure on the walls on which they rest.

2d. Those in which advantage is taken of the strength of the walls to resist a side thrust, as in many of the Gothic open timbered roofs.

109. *Trussed Roofs, exerting no Side Thrust on the Walls.*—In roofs of this kind each truss consists essentially of a pair of principal rafters or *principals*, and a horizontal *tie beam*, and in large roofs these are connected and strengthened by *king and queen posts* and *struts* (see figs. 51. and 52).

Fig. 50 shows a very simple truss in which the tie is above the bottom of the feet of the principals, which is often done

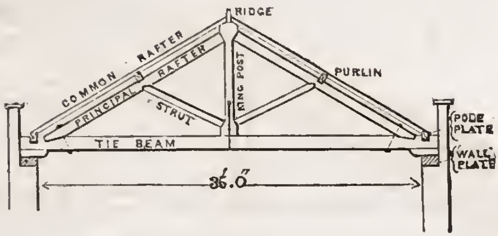
Fig. 50.



in small roofs for the sake of obtaining height. The tie in this case is called a *collar*. The feet of both common and principal rafters rest on a *wall plate*. The purlins rest on the collar, and the common rafters but against a *ridge* running along the top of the roof. This kind of truss is only suited to very small spans, as there is a cross strain on that part of the principals below the collar, which is rendered harmless in a small span by the extra strength of the principals, but which in a large one would be very likely to thrust out the walls.

110. In roofs of larger span the tie beam is placed below the feet of the principals, which are tenoned into, and bolted to it. To keep the beam from *sagging*, or bending by its own weight, it is suspended from the head of the principals by a king post of wood or iron. The lower part of the king post affords abutments for struts supporting the principals immediately under the purlins, so that no cross strain is exerted on any of the timbers in the truss, but they all act in the direction of their length, the principals and struts being subjected to compression, and the king post and tie beam to tension. Fig. 51 shows a sketch of a king truss. The com-

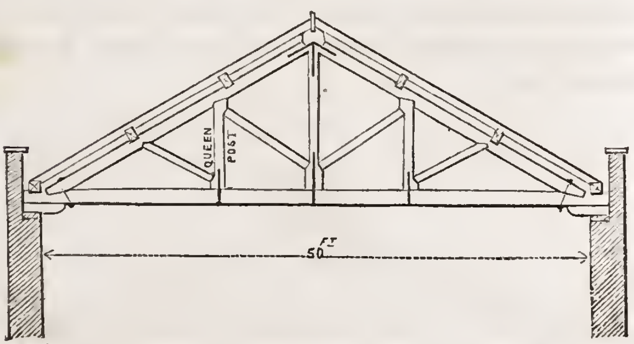
Fig. 51.



mon rafters but on a *pole plate,* the tie beams resting either on a continuous plate, or on short templates of wood or stone.

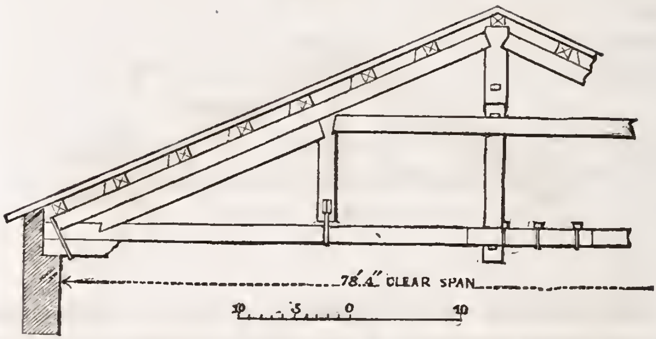
111. Where the span is considerable, the tie beam is supported at additional points by suspension pieces called queen posts (fig. 52), from the bottom of which spring additional

Fig. 52.



struts; and, by extending this principle *ad infinitum,* we might construct a roof of any span, were it not that a practical limit is imposed by the nature of the materials. Sometimes roofs are constructed without king posts, the queen posts being kept apart by a straining piece. This construction is shown in fig. 53, which shows the design of the old

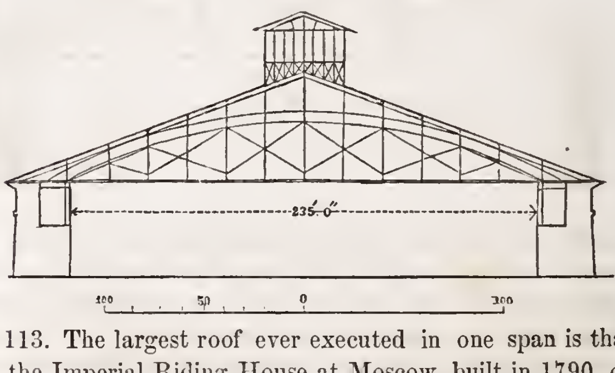
Fig. 53.



roof (now destroyed) of the church of St. Paul, outside the walls, at Rome. This truss is interesting from its early date, having been erected about 400 years ago ; the trusses are in pairs, a king post being keyed in between each pair to support the tie beams in the centre.

112. Of late years iron has been much used as a material for the trusses of roofs, the tie beams and suspending pieces being formed of light rods, and the principals and struts of rolled T or angle iron, to which sockets are riveted to receive the purlins.

Fig. 54.



113. The largest roof ever executed in one span is that of the Imperial Riding House at Moscow, built in 1790, of which the span is 235 ft. (fig. 54). The principal feature in

this roof is an arched beam, the ends of which are kept from spreading by a tie beam, the two being firmly connected by suspension pieces and diagonal braces: the arched beam (fig. 55), is formed of three thicknesses of timber, notched

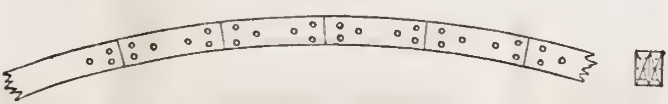
Fig. 55.

out to prevent their sliding on each other,—a method which is objectionable on account of the danger of the splitting of the timber under a considerable strain.

114. The principle of the *bow suspension truss*, as this system of trussing is called, has been much used within the last ten years for railway bridges and similar works. One of the best executed works of this kind is a bridge over the River Ouse, near Downham Market, in Norfolk, on the line of the Lynn and Ely Railway, the trusses of which are 150 ft. span.

115. *Roofs on the principle of the Arch.*—In the 16th century, Philibert de Lorme, a celebrated French architect, published a work, in which he proposed to construct roofs and domes with a series of arched timber ribs in place of trusses, these ribs being formed of planks in short lengths, placed edgewise, and bolted together in thicknesses, breaking joint (fig. 56). This mode of construction has been more or less used ever since the time of its author. An instance of its successful application on a large scale was the original dome of the Halle au Blé, at Paris, 120 ft. in diameter, built by Messrs. Legrand and Molino. This roof has since been

Fig. 56.

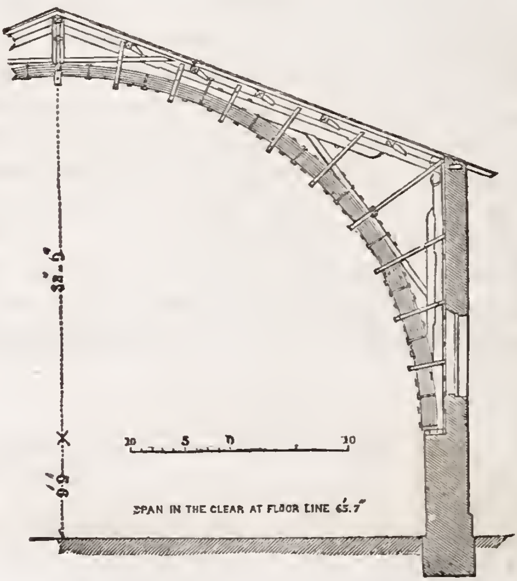


replaced by an iron one, the original dome having been destroyed by fire.

116. There are, however, some great disadvantages, connected with this system. There is considerable waste of material; the labor is great as compared with roofs of similar span of the ordinary construction; and, as the chief strength of the rib depends upon the lateral cohesion of the fibres of the wood, it is necessary to provide such an amount of surplus strength as shall insure it against the greatest cross strain to which it can be exposed from violent winds or otherwise.

117. Struck by these disadvantages, Colonel Emy, a French military engineer, proposed, in 1817, an improvement on the system of Philibert de Lorme, which was precisely the laminated arched rib so much in use at the present day. It was not until 1825 that he obtained permission to put his design into execution in the erection of a large roof 65 ft. span at Marac, near Bayonne (fig. 57). The ribs in

Fig. 57.



this roof are formed of planks bent round on templets to the proper curve, and kept from separating by iron straps, and also by the radiating struts which are in pairs, notched out so as to clip the rib between them.

The principle of the roof is exceedingly good. The principals, wall-posts, and arched rib, form two triangles, firmly braced together, and exerting no *thrust* on the walls ; and the weight of the whole roof being thrown on the walls at the feet of the ribs, and not at the pole plate, the walls are not tried by the action of a heavy roof, and the consequent saving in masonry is very great.

The great difference in principle between the arched rib of Philibert de Lorme, and the laminated rib of Colonel Emy is, that in the latter the direction of the fibre of the wood coincides with the curvature of the rib ; and, as a consequence of this, the joints are much fewer ; the rib possesses considerable elasticity, so as slightly to yield rather than break under any violent strain ; and, from the manner in which the planks are bolted together, it is impossible for the rib to give way, unless the force applied be sufficient to crush the fibres.

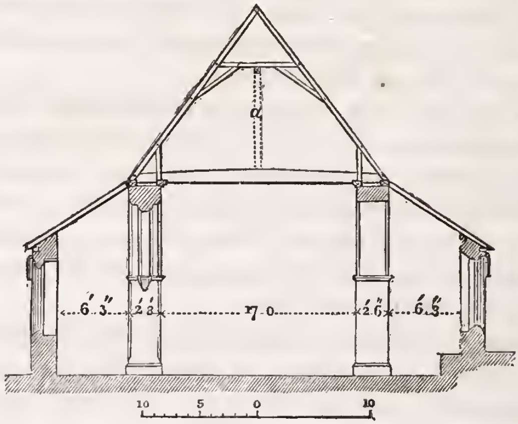
The principle of the laminated arched rib has been extensively used in the erection of railway bridges in England.

118. *Gothic Roofs.*—The open timber roofs of the middle ages come, for the most part, under the second class, viz., those which exert more or less thrust upon the walls, although there are many fine examples in which this is not the case.

We propose to describe the principal varieties of these roofs, without reference either to their decorative details, or to their chronological arrangement, our object here being simply to explain the principles on which they were constructed.

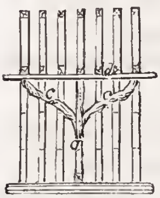
119. Fig. 58, which is a section of the parish church of Chaldon, near Merstham in Surrey, shows a system of roofing formerly very common. This may be compared to single

Fig. 58.



flooring, as there are no principals, purlins, or even ridge. It is a defective form of roof, as the rafters have a tendency to spread and thrust out the walls. In the example before us, this effect has been prevented by the insertion of tie-beams, from which the collars have been propped up (fig. 59), thus, in fact, balancing the roof on the centres of the collars, which are in consequence violently strained.

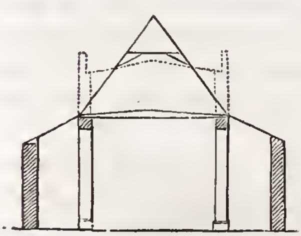
Fig. 59.



a post ; *b* sill ; *c c* struts.

120. After the introduction of the four centered arch, a great many church roofs of the construction just described were altered, as shown by the dotted lines in fig. 60, in order to obtain more light by the introduction of clerestory windows over the nave arches. The flat roofs, which superseded the former ones, were often formed without any truss whatever, being simply an arrangement of main beams, purlins, and rafters, precisely similar to a double-framed floor, with the

Fig. 60.



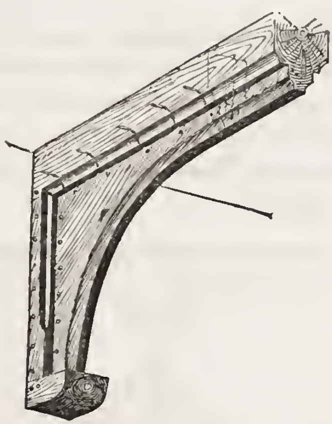
difference only that the main beams, instead of being perfectly straight, were usually cut out of crooked timber so as to divide the roof into two inclined planes.

To throw the weight of the roof as low down as possible, the ends of the main beams are often supported on upright posts placed against the walls and resting on projecting corbels, the wall posts and beams being connected by struts in such a way that deflection in the centre of the beam cannot take place, unless the load be sufficient to force out the walls, as shown by the dotted lines in fig. 61

Fig. 61.

The struts are often cut out of stout plank, forming solid spandrils, the edges of which are moulded to suit the profile of the main beam (see fig. 62), which also shows the manner of securing the struts to the wall posts and to the beam with *tongues* and wooden pins.

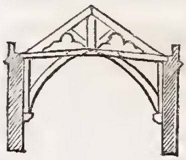
Fig. 62.



121. Fig. 63 exhibits a construction often to be met with, which, in general appearance, resembles a trussed king post roof, but which is in reality very different, the tie beam being a strong girder supporting the king post, which, in-

stead of serving to suspend the tie-beam from the principals, is a prop to the latter. In this and the previous example, any tending to deflection of the tie-beam is prevented by struts : the weight of the roof is thrown by means of wall posts considerably below the feet of the rafters, so that the weight of the upper part of the wall is made available to resist the thrust of the struts.

Fig. 63.

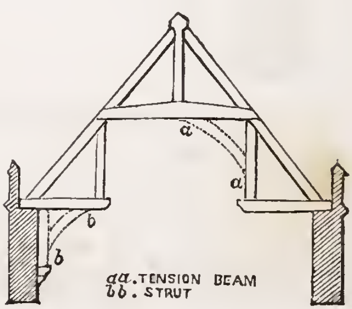


122. The roofs we have been describing are not to be recommended as displaying any great amount of constructive skill. Indeed, although they answer very well for small spans with timbers of large scantling and side walls of sufficient thickness to resist a considerable thrust, they are totally unsuited to large spans, and are in every way inferior to trussed roofs.

The above remarks do not apply to the high pitched roofs of the large halls of the fifteenth and sixteenth centuries, which, for the most part, are trussed in a very perfect manner, so as to exert no thrust upon the walls ; although, in some instances, as at Westminster Hall, they depend upon the latter for support.

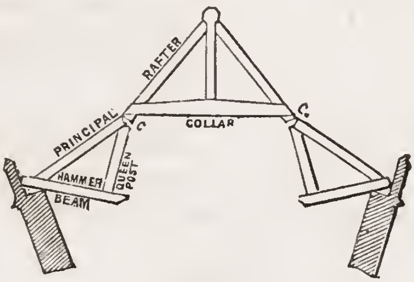
The general design of these roofs is shown in figs. 64 and

Fig 64.



65. The essential parts of each truss are, a pair of principals connected by a collar or *wind beam,* and two *hammer beams,* with queen posts over them, the whole forming three triangles, which, if not secured in their relative positions, otherwise than by the mere transverse strength of the principals, would turn on the points *c c* (fig. 65), the weight of the roof thrusting out the walls in the manner shown in the figure. There are two ways in which a truss of this kind

Fig. 65.

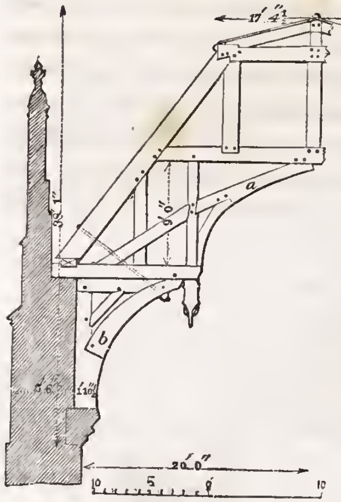


may be prevented from spreading. 1st, The ends of the hammer beams may be connected with the collar by tension pieces, *a a* (fig. 64), by which the thrust on the walls will be converted into a vertical pressure. 2d, The hammer beams may be kept in their places by struts, *b b*, the walls being made sufficiently strong by buttresses, or otherwise, to resist the thrust.

In existing examples, we find sometimes one and sometimes the other of these plans followed ; and occasionally both methods are combined in such a manner that it is often difficult to say what parts are in a state of compression, and what are in a state of tension.

123. The roof of the great hall at Hampton Court (fig. 66) is very strong, and so securely tied, that were the

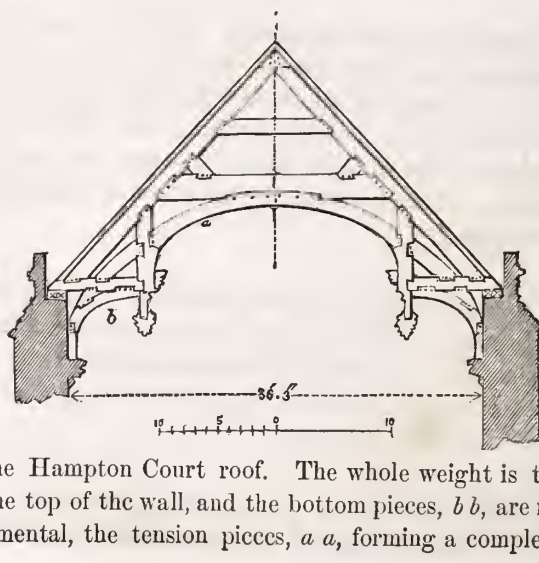
Fig. 66



bottom struts, *b b*, removed, there would be little danger of the principals thrusting out the walls; and, on the other hand, from the weight of the roof being carried down to a considerable distance below the hammer beams by the wall posts, the walls themselves offer so much resistance to side thrust, that there would be no injurious strain on them were the tension pieces, *a a*, removed.

124. The construction of the roof of the hall at Eltham Palace, Kent (fig. 67), differs very considerably from that

Fig. 67.

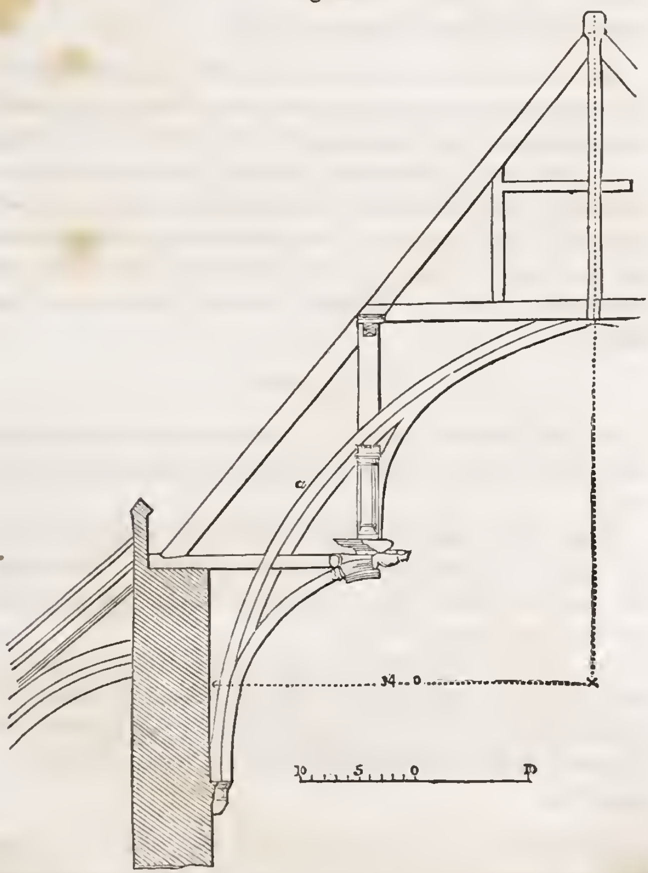


of the Hampton Court roof. The whole weight is thrown on the top of the wall, and the bottom pieces, *b b*, are merely ornamental, the tension pieces, *a a*, forming a complete tie.

This has been shown by a partial failure which has taken place. The wall plates having become rotten in consequence of the gutters being stripped of their lead, the weight has been thrown on the pseudo struts, which have bent under the pressure, and forced out the upper portion of the walls.

125. The roof of Westminster Hall (fig. 68) is one of the finest examples now existing of open timbered roofs. The

Fig. 68.



peculiar feature of this roof is an arched rib in three thick

nesses, something on the principle of Philibert de Lorme; but it is so slight, compared with the great span, that it is probable, in designing the roof, the architect took full advantage of the support afforded by the thickness of the walls and the buttresses; if, indeed, the latter were not added at the time the present roof was erected, in 1395. It has been ascertained that the weight of the roof rests on the top of the walls, the lower part of the arched rib only serving to distribute the thrust, and to assist in preventing the hammer beams from sliding on the walls.

126. The mediæval architects generally employed oak in the construction of their large roofs, the timbers being morticed and pinned together, as shown in fig. 62. This system of construction is impossible in fir and other soft woods, in which the fibres have little lateral cohesion, as the timber would split with the strain; and therefore, in modern practice, it is usual to secure the connections with iron straps or bolts passing round or through the whole thickness of the timbers.

ROOF COVERINGS.

127. The different varieties of roof coverings principally used may be classed under three heads: stone, wood, and metal.

Of the first class, the best kind is slate, which is used either sawn into slabs or split into thin laminæ. The different sizes of roofing slate in common use are given in the description of Slaters' Work.

In many parts of England, thin slabs of stone are used in the same way as roofing slate. In the Weald of Sussex the stone found in the locality is much used for this purpose, but it makes a heavy covering, and requires strong timbers to support it.

128. *Tiles* are of two kinds: *plain tiles*, which are quite flat; and *pantiles*, which are of a curved shape, and lap over

each other at the sides. Each tile has a projecting ear on its upper edge, by which it is kept in its place. Sometimes plain tiles are pierced with two holes, through which oak pins are thrust for the same purpose.

129. Wooden coverings are little used at the present day, except for temporary purposes ; *shingles* of split oak were formerly much used, and may still be seen on the roofs of some country churches. Cedar shingles are much used.

130. *Metallic Coverings.*—The metals used for roof coverings are lead, zinc, copper, and iron.

131. Lead is one of the most valuable materials for this purpose on account of its malleability and durability, the action of the atmosphere having no injurious effect upon it. Lead is used for covering roofs in sheets weighing from 4 to 8 lbs. per sup. foot.

132. Copper is used for covering roofs in thin sheets weighing about 16 oz. per sup. foot, and from its lightness and hardness has some advantages over lead ; but the expense of the metal effectually precludes its general adoption.

133. Zinc has of late years superseded both lead and copper to a considerable extent as roof coverings. It is used in sheets weighing from 12 oz. to 20 oz. per sup. foot. It is considered an inferior material to those just named ; but its lightness and cheapness are great recommendations, and the manufacture has been much improved since its first introduction.

134. Cast iron, coated with zinc to preserve it from rusting, is now much used in a variety of forms. We have already mentioned its adoption for covering the roofs of the New Houses of Parliament.

135. All metallic coverings are subject to contraction and expansion with the changes of the temperature, and great

care is requisite in joining the sheets to make them lap over each other, so as to make the joints water-tight, without preventing the play of the metal.

The following table of the comparative weights of different roof coverings may be useful :—

	Cwts.	qrs.	lbs.
Plain tiles, per square of 100 ft. sup. .	18	0	0
Pantiles	9	2	0
Slating, an average	7	0	0
Lead, 7 lb. to the sup. foot	6	2	0
Copper or zinc, 16 oz. do.	1	0	0

SUPPLY OF WATER.

136. The arrangements for distributing a supply of water over the different parts of a building will depend very materially on the nature of the supply, whether constant or intermittent.

The most common method of supply from water-works is by pipes which communicate with private cisterns, into which the water is turned at stated intervals.

A cistern, in a dwelling-house, is always more or less an evil ; it takes up a great deal of space, costs a great deal of money in the first instance, and often causes inconvenience, from leakage, from the bursting of the service pipes in frosty weather, and from the liability of the self-acting cock to get out of order.

Fig. 68 shows the ordinary arrangements of a cistern for a dwelling-house. The common material for the cistern itself is wood lined with sheet lead ; but slate cisterns have been much used of late. Large cisterns or tanks for the supply of breweries, manufactories, &c., are usually made of cast-iron plates, screwed together by means of flanges all round their edges.

The service or feed pipe for a cistern, in the case of an

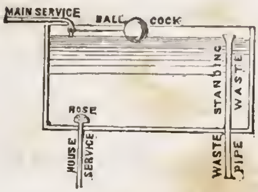
ENTRANCE TO THE MARKET PLACE;

FORMERLY SUPPOSED TO BE A PART OF A TEMPLE DEDICATED TO AUGUSTUS

page 275 6.

intermittent supply, must be sufficiently large to allow of its filling during the time the water is turned on from the mains. The flow of water into the cistern is regulated by a *ball cock*, so called from its being opened and shut by a lever, with a copper ball, which floats on the surface of the water.

Fig. 69.



The service pipes to the different parts of the building are laid into the bottom of the cistern, but should not come within an inch of the actual bottom, in order that the sediment, which is always deposited in a greater or less degree, may not be disturbed : the mouth of each pipe should be covered by a *rose*, to prevent any foreign substances being washed into the pipes and choking the taps.

To afford a ready means of cleaning out the cistern, a waste pipe is inserted quite at the bottom, sufficiently large to draw off the whole contents in a short time when required ; into this waste pipe is fitted a *standing waste*, which reaches nearly to the top of the cistern, and carries off the waste water, when, from any derangement in the working of the ball cock, the water continues running after the cistern is full. To prevent any leakage at the bottom of the standing waste, the latter terminates in a brass plug, which is ground to fit a washer inserted at the top of the waste pipe.

Where the supply of water is *constant*, instead of being intermittent, private cisterns may be altogether dispensed with ; the main service pipes, not being required to discharge a large quantity of water in a short time, may be of smaller bore, and, consequently, cheaper, and a considerable length of pipe is saved, as the water can be laid on directly to the several taps, instead of having to be taken up to the cistern and then brought back again. The constant flow of water through the pipes also much diminishes the risk of their bursting in frosty weather from freezing of their contents.

WARMING AND VENTILATION.

137. The various contrivances employed for warming buildings may be classed as under :—

Methods of Warming independently of Ventilation.

1st. By close stoves, the heating surface being either of iron or of earthenware

2d. By hot-air flues, passing under the floors.

3d. By a system of endless piping heated by a current of hot water from a boiler, the circulation being caused by the cooling, and consequently greater weight, of the water in the lower or returning pipe.

Methods of Warming combined with Ventilation.

4th. By open fires placed in the several apartments.

5th. By causing air which has been previously heated to pass through the several rooms. This last system is more perfect than any of the others above described, both as regards economy of fuel and regulation of the temperature.

A great though common defect in the construction of fire-places is their being placed too high ; whence it is not unusual for the upper part of a room to be quite warm whilst there is a stratum of cold air next the floor, the effect of which is very injurious to health.

In all methods of warming, in which the air is heated by coming in contact with metallic heating surfaces, care should be taken that their temperature should not exceed 212° ; as, when this limit is exceeded, the air becomes unfit for use, and offensive from the scorching of the particles of dust or other matters that are always floating in it.

138. There are two modes in which artificial ventilation is effected, each of which is very efficient.

The one most in use is to establish a draught in an air

shaft or chimney communicating by flues with the apartments to be ventilated, the effect of which is to cause a constant current in the direction of the shaft, the air being admitted at the bottom of the building, and warmed or cooled as may be required, according to the season of the year.

The new House of Lords is ventilated in this manner. The air is admitted at the bottom of the buildings, filtered by being passed through fine sieves, over which a stream of water is constantly flowing; warmed in cold weather by passing through steam cockles, and then, rising through the building, goes out through the roof into the furnace chimney, the draught being assisted by a steam jet from a boiler.

139. The other mode of ventilation to which we have alluded is on a completely opposite principle to that just described, the air being *forced into* the apartments by mechanical means, instead of being *drawn from* them by the draught in the chimney.

In "THE AMERICAN COTTAGE BUILDER" the Editor treats this subject more fully, and in detail.

SECTION II.

MATERIALS USED IN BUILDING.

140. The materials used in building may be classed under the following heads, viz :

Timber, Stone, Slate, Bricks and Tiles, Limes and Cements, Metals, Glass, Colors and Varnishes.

TIMBER.

141. If we examine a transverse section of the stem of a tree, we perceive it to consist of three distinct parts : the *bark*, the *wood*, and the *pith*. The wood appears disposed in rings round the pith, the outer rings being softer and containing more sap than those immediately round the pith which form what is called the *heart wood*.

These rings are also traversed by rays extending from the centre of the stem to the bark, called *medullary rays*.

The whole structure of a tree consists of minute vessels and cells, the former conveying the sap through the wood in its ascent, and through the bark to the leaves in its descent ; and the latter performing the functions of secretion and nutrition during the life of the tree. The solid parts of a tree consist almost entirely of the fibrous parts composing the sides of the vessels and cells.

By numerous experiments it has been ascertained that the sap begins to ascend in the spring of the year, through the minute vessels in the wood, and descends through the bark to the leaves, and, after passing through them, is deposited in an altered state between the bark and the last years's wood, forming a new layer of bark and sap wood, the old bark being pushed forward.

As the annual layers increase in number, the sapwood

ceases to perform its original functions; the fluid parts are evaporated or absorbed by the new wood, and, the sides of the vessels being pressed together by the growth of the latter, the sap wood becomes heart wood or perfect wood, and until this change takes place it is unfit for the purposes of the builder.

The vessels in each layer of wood are largest on the side nearest the centre of the stem, and smallest at the outside. This arises from the first being formed in the spring, when vegetation is most active. The oblong cells which surround the vessels are filled with fluids in the early growth; but, as the tree increases in size, these become evaporated and absorbed, and the cells become partly filled with depositions of woody matter and indurated secretions, depending on the nature of the soil, and affecting the quality of the timber. Thus Honduras mahogany is full of black specks, while the Spanish is full of minute white particles, giving the wood the appearance of having been rubbed over with chalk. At a meeting of the Institution of Civil Engineers, March, 1842, it was stated by Professor Brande, that "a beech tree in Sir John Sebright's park in Hertfordshire, on being cut down, was found perfectly black all up the heart. On examination it was discovered that the tree had grown upon a mass of iron scoriæ from an ancient furnace, and that the wood had absorbed the salt of iron." This anecdote well explains the differences that exist between different specimens of the same kind of timber under different circumstances of growth; and it is probably the nature of the soil that causes the difference of character we have just named between Honduras and Spanish mahogany.

There is a great difference in the character of the annual rings in different kinds of trees. In some they are very distinct, the side next the heart being porous, and the other being compact and hard, as the oak, the ash, and the elm. In others the distinctions between the rings is so small as scarcely to be distinguished, and the texture of the wood is

nearly uniform, as in the beech and mahogany. A third class of trees have the annual rings very distinct and their pores filled with resinous matter, one part being hard and heavy, the other soft and light-colored. All the resinous woods have this character, as larch, fir, pine, and cedar.

The medullary rings are scarcely perceptible to the naked eye in the majority of trees; but in some, as the oak and the beech, there are both large and small rings, which, when cut through obliquely, produced the beautiful flowered appearance called the silver grain.

142. In preparing timber for the uses of the builder there are three principal things to be attended to, viz., the age of the tree, the time of felling, and the seasoning for use.

143. If a tree be felled before it is of full age, whilst the heartwood is scarcely perfected, the timber will be of inferior quality, and, from the quantity of sap contained in it, will be very liable to decay. On the other hand, if the tree be allowed to stand until the heartwood begins to decay, the timber will be weak and brittle: the best timber comes from trees that have nearly done growing, as there is then but little sapwood, and the heartwood is in the best condition.

144. The best time for felling trees is either in mid-winter, when the sap has ceased to flow, or in mid-summer, when the sap is temporarily expended in the production of leaves. An excellent plan is to bark the timber in the spring and fell it in winter, by which means the sapwood is dried up and hardened; but as the bark of most trees is valueless, the oak tree (whose bark is used in tanning) is almost the only one that will pay for being thus treated.

145. The seasoning of timber consists in the extraction or evaporation of the fluid parts, which are liable to decomposition on the cessation of the growth of the tree. This is usually effected by steeping the green timber in water, to dilute and wash out the sap as much as possible, and then

drying it thoroughly by exposure to the air in an airy situation. The time required to season timber thoroughly in this manner will of course much depend on the sizes of the pieces to be seasoned ; but for the general purposes of carpentry, two years is the least that can be allowed, and, in seasoning timber for the use of the joiner, a much longer time is usually required.

146. *Decay of Timber.*—Properly seasoned timber, placed in a dry situation with a free circulation of air round, it is very durable, and has been known to last for several hundred years without apparent deterioration. This is not, however, the case when exposed to moisture, which is always more or less prejudical to its durability.

When timber is constantly under water, the action of the water dissolves a portion of its substance, which is made apparent by its becoming covered with a coat of slime. If it be exposed to alternations of dryness and moisture, as in the case of piles in tidal waters, the dissolved parts being continually moved by evaporation and the action of the water, new surfaces are exposed, and the wood rapidly decays.

Where timber is exposed to heat and moisture, the albumen or gelatinous matter in the sapwood speedily putrefies and decomposes, causing what is called rot. The rot in timber is commonly divided into two kinds, the *wet* and the *dry*, but the chief difference between them is, that where the timber is exposed to the air, the gaseous products are freely evaporated ; whilst, in a confined situation, they combine in a new form, viz., the dry-rot fungus, which, deriving its nourishment from the decaying timber, often grows to a length of many feet, spreading in every direction, and insinuating its delicate fibres even through the joints of brick walls.

In addition to the sources of decay above mentioned, timber placed in sea-water is very liable to be completely destroyed by the perforations of the worm, unless protected by

copper sheathing, the expense of which causes it to be seldom used for this purpose.

147. *Prevention of Decay.*—The best method of protecting woodwork from decay when exposed to the weather is to paint it thoroughly, so as to prevent its being affected by moisture. It is, however, most important not to apply paint to any woodwork which has not been thoroughly seasoned; for in this case the evaporation of the sap being prevented, it decomposes, and the wood rapidly decays.

Many plans have been proposed for preventing the rot.

148. For a list of the varieties of timber for building purposes, see Appendix.

149. For internal finishings, mahogany is much used; that called Spanish, which comes from the West India Islands is considered the best.

For joiners' and cabinet makers' work, a great many kinds of fancy wood are imported, which are cut by machinery into thin slices, called *veneers*, and used as an ornamental covering to inferior work. In veneering care should be taken that the body of the work be thoroughly seasoned, or it will shrink, and the veneer fly off.

LIMES AND CEMENTS, MORTAR, ETC.

150. So much of the stability of brickwork and masonry depends upon the binding properties of the mortar or cement with which the materials are united, especially when exposed to a side pressure, as in the case of retaining walls, arches, and piers, that it is of no small importance to ascertain on what the strength of mortar really depends, and how far the proportions of the ingredients require modification, according to the quality of the lime that may have to be used.

It was long supposed that the hardness of any mortar depended upon the hardness of the limestone, from which the

lime used in its composition was derived ; but it was ascertained by the celebrated Smeaton, and since his time clearly shown by the researches of others, amongst whom may be named, Vicat in France, and Colonel Pasley in England, that the hardness of the limestone has nothing to do with the matter, and that it is its chemical composition which regulates the quality of the mortar.

151. Limestone may be divided into three classes:

1st. Pure limes—as chalk.

2d. Water limes—some of which are only slightly hydraulic, as the stone limes of the lower chalk, whilst others are eminently so, as the lias limes.

3d Water cements—as those of Sheppy and Harwich.

152. In making mortar the following processes are gone through:

1st. The limestone is calcined by exposure to strong heat in a kiln, which drives off the carbonic acid gas contained in it, and reduces it to the state of *quick-lime.*

2d. The quick-lime is *slaked* by pouring water upon it, when it swells, more or less, with considerable heat, and falls into a fine powder, forming a *hydrate* of lime.

3d. The hydrate thus formed is mixed up into a stiffish paste, with the addition of more water, and a proper proportion of sand, and is then ready for use.

153. *Pure Limes.—Chalk* is a pure carbonate of lime, consisting of about 5 parts of lime combined with 4 of carbonic acid gas. It expands greatly in slaking, and will bear from three to 3½ parts of sand to one of lime, when made up into mortar. Chalk lime mortar is, however, of little value, as it *sets* or hardens very slowly, and in moist situations never sets at all, but remains in a pulpy state, which renders it quite unfit for any work subjected to the action of water, or even for the external walls of a building.

154. Gypsum, from which is made *plaster of Paris* for cornices and internal decorations, is granular sulphate of lime, and contains 26·5 of lime, 37·5 of sulphuric acid, and 17 of water. It slakes without swelling, with a moderate heat, setting hard in a very short time, and will even set under water; but as it is, like other pure limes, partly soluble in water, it is not suitable for anything but internal work.

155. *Water limes* have obtained their name from the property they possess, in a greater or less degree, of setting under water. They are composed of carbonate of lime, mixed with silica, alumina, oxide of iron, and sometimes other substances.

156. *Dorking lime*, obtained from the beds of the lower chalk, at Dorking, in Surrey; and *Halling lime*, from a similar situation near Rochester, in Kent, are the principal limes used in London for making mortar, and are slightly hydraulic; they expand considerably in slaking, but not so much as the pure limes, and will make excellent mortar when mixed with three parts of sand to one of lime. Mortar made with these limes sets hard and moderately quick, and *when set*, may be exposed to considerable moisture without injury; but they will not set under water, and are therefore unfit for hydraulic works, unless combined with some other substance, as *puzzolana*, to give them water-setting properties.

157. The *blue lias limes* are the strongest water limes in this country. They slake very slowly, swelling but little in the process, and set very rapidly even under water; a few days only sufficing to make mortar extremely hard. The lias limes will take a much smaller proportion of sand than the pure limes, the reason of which will be understood, when it is remembered that they contain a considerable proportion of silica and alumina, combined with the lime in their natural state, and consequently the proportion of sand which

makes good mortar with chalk lime, would ruin mortar made with lias limes.

In the Vale of Belvoir, where the lias lime is extensively used, the common practice is to use equal parts of lime and sand for inside, and half sand to one of lime for face work.

158. *Water Cements.*—These differ from the water limes, as regards their chemical composition, only in containing less carbonate of lime and more of silica and alumina. They require to be reduced to a fine powder after calcination, without which preparation they cannot be made to slake. The process of slaking is not accompanied by any increase of bulk, and they set under water in a short time, a few hours sufficing for a cement joint to become perfectly hard.

Cement will not bear much sand without its cementitious properties being greatly weakened, the usual proportion being equal parts of sand and cement.

159. The use of natural cement was introduced by Mr. Parker, who first discovered the properties of the cement-stone in the Isle of Sheppy, and took out a patent for the sale of it in 1796, under the name of Roman cement.

Before that time, hydraulic mortar, for dock walls, harbor work, &c., was usually made, by mixing common lime with trass, from Andernach in Germany, or with puzzolana from Italy ; both are considered to be volcanic products, the latter containing silica and alumina, with a small quantity of lime, potash, and magnesia. Iron is also associated with it in a magnetic state.

160. The expense of natural puzzolana led to the manufacture of artificial puzzolana, which appears to have been used at an early date by the Romans, and has continued in use in the south of Europe to the present day ; artificial puzzolana is made of pounded bricks or tile dust. The Dutch manufacture an artificial puzzolana from burnt clay,

in imitation of the trass of Andernach, which is said to be a close imitation of the natural product.

161. The great and increasing demand for cement, and its great superiority for most purposes over lime mortar, have induced manufacturers to turn their attention to the manufacture of artificial cement, and this has been attended in many instances with perfect success ; the artificial cements now offered for sale, formed by imitating the composition of the natural cement-stones, being mostly equal in quality, if not superior, to the Roman cement, the use of which has been partly superseded by them.

162. The quality of the *sand* used in making mortar is by no means unimportant. It should be clean and sharp ; *i. e.*, angular, and perfectly free from all impurities. The purer the lime the finer should be the quality of the sand, the pure limes requiring finer, and the cements a coarser sand, than the hydraulic limes.

CONCRETE AND BETON.

163. Rubble masonry, formed of small stones bedded in mortar, appears to have been commonly used in England from an early period ; and similar work, cemented with hydraulic mortar, was constantly made use of by the Romans in their sea-works, of which many remains exist at the present day in a perfectly sound state.

164. This mode of forming foundations, in situations where solid masonry would be inapplicable, has been revived in modern times ; in England and the United States under the name of concrete, and on the continent under the name of béton. Although very similar in their nature and use, there are yet great differences between béton and concrete, which depend on the nature of the lime used, concrete being made with the weak water limes which will not set under water, whilst béton is invariably made with water-setting limes, or

with limes rendered hydraulic by the addition of puzzolana. Describing the two by their differences, it may be observed that concrete is made with unslaked lime, and immediately thrown into the foundation pit ; béton is allowed to stand before use, until the lime is thoroughly slaked ; concrete is thrown into its place and rammed to consolidate it ; béton is generally lowered and not afterwards disturbed ; concrete must be thrown into a dry place, and not exposed to the action of water until thoroughly set ; béton, on the contrary, is made use of principally *under water*, to save the trouble and expense of laying dry the bottom.

165. Concrete is usually made with gravel, sand, and ground unslaked lime, mixed together with water, the proportions of sand and lime being those which would make good mortar without the gravel, and, of course, varying according to the quality of the lime ; with the common limes, slaking takes place at the time of mixing, and the quality of the concrete is all the better for the freshness of the lime. If lias lime be used, the concrete becomes béton, and must be treated accordingly.

The lime in this case must be thoroughly slaked (which often takes many hours) before it can be considered fit for use ; and, if this precaution be not attended to, the whole of the work, after having set very hard on the surface, cracks and becomes a friable mass, from the slaking of the refactory particles after the body of the concrete has set.

166. Asphalte, so much in use at the present day for foot-pavements, terrace-roofs, &c., is made by melting the asphalte rock, which is a carbonate of lime intimately combined with bitumen, and adding to it a small portion of mineral tar, which forms a compact semi-elastic solid, admirably adapted for resisting the effects of frost, heat, and wet.

Many artificial asphaltes have been brought under public notice from time to time, but they are all inferior to the natural asphalte, in the intimate combination of the lime and

bitumen, which it appears impossible to effect thoroughly by artificial means.

METALS.

167. The metals used as building materials are iron, lead, copper, zinc, and tin.

168. *Iron.*—Iron is used by the builder in two different states, viz., cast iron and wrought iron, the differences between them depending on the proportion of carbon combined with the metal; cast iron containing the most, and wrought iron the least.

169. Previous to the middle of the last century, the smelting of iron was carried on with wood charcoal, and the ores used were chiefly from the secondary strata, although the clay ironstones of the coal measures were occasionally used.

170. The introduction of smelting with pitcoal coke during the last century caused a complete revolution in the iron trade. The ores now chiefly used are the clay ironstones of the coal measures, and the fuel, pitcoal, or coke. Steam power is almost exclusively used for the production of the blast in the furnaces, and for working the forge hammers and rolling mills.

171. For the production of wrought iron in the ordinary manner, two distinct sets of processes are required. 1st. The extraction of the metal from the ore in the shape of cast iron. 2nd. The conversion of cast iron into malleable or bar iron, by re-melting, puddling, and forging. The conversion of bar iron into steel is effected by placing it in contact with powdered charcoal in a furnace of cementation.

172. *Cast iron* is produced by smelting the previously calcined ore in a blast furnace, with a portion of limestone as a flux, and pitcoal or coke as fuel. The melted metal sinks to the bottom of the furnace by its greater specific gravity.

The limestone and other impurities float on the top of the melted mass, and are allowed to run off, forming *slag* or *cinder*. The melted metal is run off from the bottom of the furnace into moulds, where castings are required, and into furrows made in a level bed of sand, when the metal is required for conversion into malleable iron, the bars thus produced being called *pigs*.

173. In the year 1827, it was discovered that by the use of heated air for the blast, a great saving of fuel could be effected as compared with the cold blast process.

The hot blast is now very extensively in use, and has the double advantage of requiring less fuel to bring down an equal quantity of metal, and of enabling the manufacturer to use raw pitcoal instead of coke, so that a saving is effected both in the quantity and cost of the fuel.

For a considerable time after its introduction it was held in great disrepute, which, however, may be chiefly attributed to the inferior quality of materials used, the power of the hot blast in reducing the most refractory ores offering a great temptation to obtain a much larger product from the furnace than was compatible with the good quality of the metal. The use of the hot blast by firms of acknowledged character has greatly tended to remove the prejudice against it; and in many iron works of high character, nothing but the hot blast with pitcoal is used in the smelting furnaces, the use of coke being confined to the subsequent processes.

Perhaps it may be laid down as a general principle, that where the pig iron is re-melted with coke in the cupola furnace, for the purposes of the iron founder; or refined with coke in the conversion of forge pig into bar iron, it is of little consequence whether the reduction of the ore has been effected with the hot or the cold blast; but where castings have to be run directly from the smelting furnace, the quality of the metal will, no doubt, suffer from the use of the former.

174. Cast iron is divided by ironfounders into three qua-

lities. No. 1, or *black cast iron*, is coarse-grained, soft, and not very tenacious. When re-melted it passes into No. 2, or *grey cast iron*. This is the best quality for castings requiring strength : it is more finely grained than No. 1, and is harder and more tenacious. When repeatedly re-melted it becomes excessively hard and brittle, and passes into No. 3, or *white cast iron*, which is only used for the commonest castings, as sash-weights, cannon-balls, and similar articles. White cast iron, if produced direct from the ore, is an indication of derangement in the working of the furnace, and is unfit for the ordinary purposes of the founder, except to mix with other qualities.

175. Girders and similar solid articles are cast in sand moulds, enclosed in iron frames or *boxes*, each mould requiring an upper and lower box. A mould is formed by pressing sand firmly round a wooden *pattern*, which is afterwards removed, and the melted metal poured into the space thus left through apertures made for the purpose.

The moulds for ornamental work and for hollow castings are of a more complicated construction, which will be better understood from actual inspection at a foundry than from any written description.

Almost all irons are improved by admixture with others, and, therefore, where superior castings are required they should not be run direct from the smelting furnace, but the metal should be re-melted in a cupola furnace, which gives the opportunity of suiting the quality of the iron to its intended use. Thus, for delicate ornamental work, a soft and very fluid iron will be required, whilst, for girders and castings exposed to cross strains, the metal will require to be harder and more tenacious. For bedplates and castings which have merely to sustain a compressing force, the chief point to be attended to is the hardness of the metal.

Castings should be allowed to remain in the sand until cool, as the quality of the metal is greatly injured by the

rapid and irregular cooling which takes place from exposure to air if removed from moulds in a red hot state, which is sometimes done in small foundries to economise room.

The Scotch iron, which is so much esteemed for hollow wares, and has a beautifully smooth surface, is much used in the United States. The Scotch iron is softer, runs closer, and is used much for plates which require smoothness, for steam-engine cylinders, and work of like character, which requires *closeness*, or soundness; it is also mixed with our American iron. The Eastern iron is the best used in the United States for positions requiring great strength. The iron from the West is more like Scotch.

The Welch iron is principally used for conversion into bar iron.

176. The conversion of forge pig into bar iron is effected by a variety of processes, which have for their object the freeing the metal from the carbon and other impurities combined with it, so as to produce as nearly as possible the pure metal. We do not purpose to enter in these pages into any of the details of the manufacture of bar iron, or of its conversion into steel, as our business is rather with the iron-founder than the manufacturer ; it may, however, be proper to state that new processes have lately been patented, by which malleable iron and steel may be produced directly from the ore, without the use of the smelting furnace, a plan which is likely to be attended with beneficial results, both as regards economy and quality of metal.

177. *Lead.*—Lead is used by the mason for securing dowels, coating iron cramps, and similar purposes, *see* section IV., Plumber.

Lead is also used by the smith in fixing iron railings, and other work where iron is let into stone ; but the use of lead in contact with iron is always to be avoided, if possible, as it has an injurious effect upon the latter metal, the part in contact with the lead becoming gradually softened.

The chief value of lead, however, to the builder, is as a covering for roofs, and for lining gutters, cisterns, &c., for which uses it is superior to any other metal. For these purposes the lead is cast into sheets, and then passed between rollers in a *flatting-mill*, until it has been reduced to the required thickness.

Cast-lead is often made by plumbers themselves from old lead taken in exchange; but it is very inferior to the *milled lead* of the manufacturer, being not so compact, and often containing small air-holes, which render it unfit for any but inferior purposes.

178. *Copper.—See* Section IV., Coppersmith.

179. *Zinc.—See* Section IV., Zincworker.

180. *Brass* is an alloy of the copper and zinc, the best proportions being nearly two parts of copper to one of zinc.

181. *Bronze* is a compound of metal, composed of copper and tin, to which are sometimes added a little zinc and lead.

The best proportions for casting statues and bas-reliefs appear to be attained when the tin forms about 10 per cent. of the alloy.

By alloying copper with tin, a more fusible metal is obtained, and the alloy is much harder than pure copper; but considerable management is required to prevent the copper from becoming refined in the process of melting, a result which has frequently happened to inexperienced founders.

182. *Bell-metal* is composed of copper and tin, in the proportion of 78 per cent. of the former to 22 per cent. of the latter.

183. Cast iron lintels and columns are in common use in our cities. Cast iron blocks are also frequently used for the arches of bridges. Iron chains are used with advantage under the roofs of circular buildings.

STONE.

184. Granite rock appears to have been originally a fused mass, and subsequently to have undergone the process of crystallization. It is of a *granular* structure, that is, consisting of separate grains of different snbstances, united, apparently, without the aid of any intermediate matter or cement. These substances are *quartz*, *felspar*, and *mica*, each of these being a componnd. The infinite variety of proportions in which their several constitnent elements are united in the mass, occasions the great diversity of color, and of appearance of the several kinds of granite, and also affects in a much more important manner the endnring characteristics of this valnable material. Thus, its color varies from light grey to a dark tint closely resembling black, and is to be found of all shades of red, and many green. Of the constituents of granite, *quartz* is a snbstance of a glassy appearance, and of a grey color, and is composed of a metallic base *silicium* and *oxygen* : *felspar* is also a crystalline substance, bnt commonly opaque, of a yellowish or pink color, composed of silicious and alnminons mattter, with a small proportion of lime and potash : *mica*, a glittering substance, principally consists of clay and flint, with a little magnesia and oxide of iron. Instead of the mica, another substance called *hornblende*, is found in some granites : hornblende is a dark crystalline substance, composed of flint, alumina, and magnesia, besides a large poportion of the black oxide of iron. Granites in which hornblende exists are sometimes called Syenite, having first been found in the island of Syene in Egypt.

185. Granite is found in monntain-chains, and usually in rngged outlines, in nearly all parts of Europe and America. Althongh all granites are similar in structure, the difference in the proportions of its constitnent snbstances occasions great difference in its enduring and nseful properties. Some

varieties are exceedingly friable and liable to decomposition, while others, including that known as Sienite, suffer but imperceptibly from moisture and the atmosphere. The compact nature of a close-grained granite, having the felspar highly crystallized and free from stains or cracks, seems well calculated to resist the effect of air and water.

186. *Slate.*—The geologists recognised four kinds of slate, *mica slate, talcows slate, flinty slate,* and common or clay slate. Of these the last only is a material of extended use in the arts of building and construction. Clay slate, as its name implies, consists chiefly of clay in an indurated condition, and occasionally containing particles of mica and quartz, and in some of the coarser kinds, grains of felspar and other fragments of the primary rocks. In the extreme admixture of these foreign substances, clay slate approaches the nature of the rock known as grey wacke. The beds of clay slate are invariably stratified, the thickness of the strata, however, varying from a fraction of an inch to many feet. Its laminar texture admits a ready separation into thin plates, and thus endows it with a supreme value for roofing and other purposes, in which great density and comparative impermeability are required to coexist with a minimum thickness and weight. The weight of slates varies from 174 to 179 lbs. per cubic foot.

187. *Sandstones.*—These rocks, belonging, geologically, to various positions in the order of the strata of which the exterior of the earth is composed. Sandstones are principally silicious, and possess various degrees of induration. These stones weigh from 140 to 150 lbs. per cubic foot.

188. From the nature of the composition of sandstones, it results that their resistance against, or yielding to, the decomposing effects to which they are subjected, depends to a great extent, if not wholly, upon the nature of the cementing substance by which the grains are united; these latter

being comparatively indestructible. From the nature of their formation, sandstones are usually laminated, and more especially so when mica is present, the plates of which are generally arranged in planes parallel to their beds. Stones of this description should be carefully placed in constructions, so that these planes of lamination may be horizontal, for if placed vertically, the action of decomposition will occur in flakes, according to the thickness of the laminæ. Indeed, the best way of using all descriptions of stone is in the same position which they had in the quarry ; but this becomes an imperative rule with those of laminated structure.

189. Uniformity of color is a tolerably correct criterion of uniformity of structure, and this constitutes, other circumstances being equal, one of the practical excellencies of building stones. The great injury occasioned to these materials by their absorption of moisture, leads properly to a preference for such stones as resist its introduction, for all above ground purposes. Those which imbibe and retain moisture are especially liable to disruption by frost, if exposed. The simplest method of finding out the disposition of stone to imbibe moisture is to immerse it for a lengthened period of time in water, and to compare the weight of it before and after such immersion.

190. *Limestones.*—The class of limestones, including the magnesian limestones and the oolites, is one of extreme importance in the building arts, comprehending some of the most advantageous materials of construction, and combining great comparative durability with peculiar facilities for working, in which they surpass the sandstones. Of the limestones and the oolites, the principal material is carbonate of lime. The magnesian limestones contain a quantity of carbonate of magnesia, in some cases nearly equal to that of carbonate of lime.

191. It is remarked that magnesian limestone appears capable of resisting decomposing action in proportion as its structure is crystalline.

SLATE.

192. *See* Section IV.

GLASS.

193. *See* Section IV.

BRICKS AND TILES.

194. According to the Bible, burnt bricks were used in the Tower of Babel.

In Egypt, bricks were made of clay, mixed with dried straw, and dried in the sun.

195. The usual form of a brick is a paralellopipedon, about 9 in. long, $4\frac{1}{2}$ in. broad, and $2\frac{1}{4}$ to 3 in. thick—the exact size varying with the construction of the clay. The thickness need not bear any definite proportion to the length and breadth, but these last dimensions require nice adjustment, as the length should exceed twice the breadth by the thickness of a mortar joint.

196. The manufacture of tiles is similar to that of bricks, the principal difference arising from the thinness of the ware.

Paving tiles may be considered simply a thin brick.

Roofing tiles are of two kinds: pantiles, which are of a curved shape, and plaintiles, which are flat, the latter being often made of ornamental shapes so as to form elegant patterns when laid on a roof.

Pantiles are moulded flat, and afterwards bent into their required shape on the mould. Plaintiles were formerly made with holes in them for the reception of the tile-pins, by which they were hung on the laths; but the common method now is to turn down a couple of nibs at the head of the tile, which answer the same purpose.

197. *Draining tiles* are the coarsest kind of earthenware. They are of various shapes, and are made in various ways.

198. Glass. *See* Section IV.

199. Colors and varnishes. *See* Section IV.

SECTION III.

STRENGTH OF MATERIALS.

200. There are three principal actions to which the materials of a building are exposed.

1st. *Compression*—as the case of the stones in a wall.

2nd. *Tension*—as in the case of a king-post or tie-beam.

3rd. *Cross-strain*—as in the case of a bressummer, floor-joists, &c.

The last of the three is the only one against which precautions are especially necessary, as in all ordinary cases the resistance of the materials used for building is far beyond any direct crushing or pulling force that is likely to be brought upon them.

201. 1st. *Resistance to Compression.*—The following table shows the force required to crush $1\frac{1}{2}$ in. cubes of several kinds of building material:—

	lbs.		lbs.
Good brick . .	1817	Portland stone . .	10,284
Derbyshire grit .	7070	Granite " . . .	14,300.

These amounts so far exceed any weight that could have to be borne on an equal area, under ordinary circumstances, that it is quite unnecessary in the erection of a building to make any calculations on this head when using these or similar materials.

Cast iron may be considered as practically incompressible ; *wrought iron* may be flattened under great pressure, but cannot be crushed. *Timber* may be considered, for practical purposes, as nearly incompressible, when the weight is applied in the direction of the fibres, as in the case of a wooden story-post ; but the softer kinds, as fir, offer little resistance,

when the weight is applied at right angles to the fibres, as in the case of the sill of a partition ; and, beside this, timber, however well-seasoned, will always shrink, more or less, in the direction of its thickness, so that no important bearings should be trusted to it.

202. 2nd. *Resistance to Tension.*—The principal building materials that are required to resist direct tension are *timber* and *wrought iron.*

The following table shows the weight in tons required to tear asunder bars 1 inch square of the following materials :—

	Tons.
Oak	5 1-6
Fir	$5\frac{1}{4}$
Cast iron	$7\frac{3}{4}$
Wrought iron	10
Wrought copper	15
English bar iron	25
American iron	$37\frac{1}{2}$
Blistered steel	$59\frac{1}{2}$

Cast iron, however, although included in the above table, is an unsuitable material for the purpose of resisting tension, being comparatively brittle. With regard to *timber*, it is practicably impossible to tear asunder a piece of even moderate size, by a force applied in the direction of the fibres, and therefore the dimensions of king-posts, tie-beams, and other timbers which have to resist a pulling force, are regulated by the necessity of forming proper joints and connections with the other parts of the framing to which they belong, rather than by their cohesive strength. But it must be borne in mind, that although the strength of all kinds of timber is very great in the direction of the fibres, the lateral cohesion of the annual rings is in many kinds of wood very slight, and must be assisted by iron straps in all doubtful cases. The architects of the middle ages executed their magnificent wooden roofs without these aids, but they worked

in oak, and not in soft fir, which would split and rend if treated in the same way.

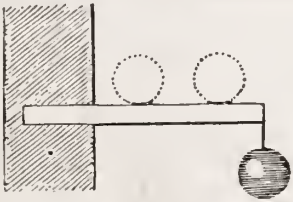
Wrought iron is extensively used for bolts, straps, tie-rods, and all purposes which require great strength, with small sectional area ; one-fourth of the breaking weight is usually said to be the limit to which it should be strained ; but, in all probability, this amount might be doubled without any injurious effects.

STRENGTH OF BEAMS.

203. 3rd. *Cross Strain.*—In calculating the strength of beams when exposed to cross or transverse strain, two principal considerations present themselves: 1st. The mechanical effect which any given load will produce under varying conditions of support: and 2ndly. The resistance of the beam, and the manner in which this is affected by the form of its section.

204. 1st. *Mechanical Effect of a given Load under varying Circumstances.*—If a rectangular beam be supported at each end and loaded in the middle, the strength of the beam, its section remaining the same, will be inversely as the distance between the supports, the weight acting with a leverage which increases at this distance * If a beam be fixed at one

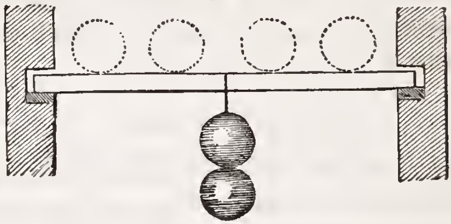
Fig. 70.



* It may be as well to observe that, although this is true as to the strength of beams under ordinary circumstances, it does not hold good when the loading is carried to the breaking point, the deflection of the beam causing an increase or diminution of the leverage according to the mode of support. The difference of strength arising from this cause is, however, too trifling to be taken into consideration, except in delicate experiments on the ultimate strength of beams.

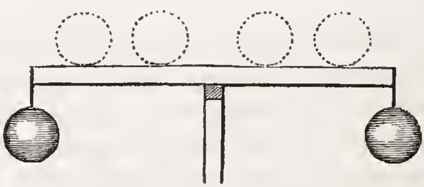
end and weighted at the other (fig. 70), its strength will be half that of a similar beam of double the length supported as first described (fig. 71). A parallel case to this is that of a beam supported in the middle and loaded at the ends

Fig. 71.



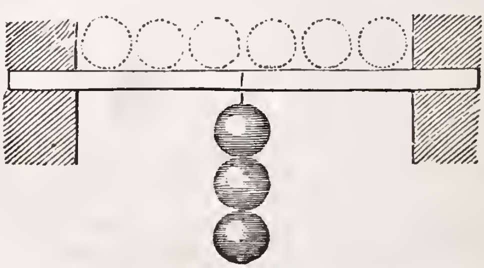
(fig. 72). In each of the above cases the beam will bear double the load if it be equally distributed over its whole

Fig. 72.



length, as shown by the dotted lines ; and lastly, the strength of a beam firmly fixed at the ends is to its strength when loosely laid on supports as 3 to 2 (*see* fig. 73).

Fig. 73.



These results may be simply expressed thus :

Let *s* be the weight which would break a beam of given length and scantling fixed at one end and loaded at the other :

then 2 *s* would break the same beam fixed at one end and uniformly loaded :

4 *s* would break the same beam supported at each end and loaded in the middle :

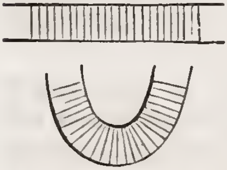
6 *s* would break the same beam fixed at each end and loaded in the middle :

8 *s* would break the same beam supported at each end and uniformly loaded :

12 *s* would break the same beam fixed at each end and uniformly loaded.

205. 2d. *Resistance of the Beam.*—If a beam be loaded so as to produce fracture, this will take place about a centre or neutral axis, below which the fibres will be *torn* asunder, and above which they will be *crushed.* This may be very clearly illustrated by drawing a number of parallel lines with a soft pencil on the edge of a piece of India rubber, and bending it round, when it will be seen that the lines are brought closer together on the concave, and stretched further asunder on the convex side, whilst, between the two edges, a neutral line may be traced, on which the divisions remain of the original size, which neutral line divides the fibres that are subjected to compression from those in a state of tension (*see* fig. 74).

Fig. 74.



The resistance of a rectangular beam will, therefore, depend, 1st, on the number of fibres, which will be proportionate to its breadth and depth ; 2d, on the distance of those fibres from the neutral axis, and the consequent leverage with which they act, which will also be as the depth ; and, lastly, on the actual strength of the fibres, which will

vary with different materials, and can only be determined approximately from actual experiments on rectangular beams of the same material as those whose strength is required to be estimated.

The actual strength of any rectangular beam will, therefore, be directly as its breadth multiplied by the square of the depth, and inversely as its length; or, calling s the transverse strength of the material, as in art. 177, b the breadth, d the depth, l the length between the supports, and W the breaking weight:

$$W = \frac{s\,b\,d^2}{l}.$$

The following may be taken as the value of s for iron and timber, the length being taken in feet, the breadth and depth in inches, and the breaking weight in pounds.

	Constant multiplier for rectangular beams fixed at one end and loaded at the oth r.		Constant multiplier for rectangular beams loosely supported at the ends and loaded in the middle.
Wrought iron	512	$\times$ 4	2048
Cast ditto	500		2000*
Fir and English oak	100		400

It must be remembered that the numbers here given indicate the breaking weight, not more than one-third of which should ever be applied in practice. Timber is permanently injured if more than even one-fourth of the breaking weight is placed on it, and, therefore, this limit should never be passed.

A single example will suffice to show the importance of the principles just explained, and the lamentable results that may follow from ignorance of them. If we take a fir binding-joist, say 9 in. $\times$ 4 in., which is to have a bearing of 12 ft. between its supports, and place it edgeways, it will require to break it a weight $= \frac{400 \times 4 \times 9^2}{12} = 10{,}800$ lbs.;

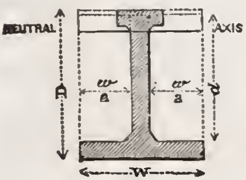
* The above is an average value calculated from a great number of published experiments on different irons.

but if, for the purpose of gaining height, we place it flat-ways, it will break with a weight $= \dfrac{400 + 9 + 4^2}{12} = 4{,}800$ lbs, or less than one-half.

206. We may see from this example that the shape of any beam has a great influence on its strength; and in making beams of iron, which can be cast with great facility in any required shape, it becomes an important question how to obtain the strongest form of section with the least expenditure of metal.

The usual section given to cast-iron girders is that of a thin and deep rectangular beam, with flanges or projections on each side at top and bottom; where the strength of the metal will be most effective, as being at the greatest possible distance from the neutral axis (fig. 78).

Fig. 78.



The great question now is, what should be the relative thickness of the top and bottom flanges, the centre part of the beam having been made as thin as is consistent with sound casting?

If the metal were incompressible, the top flanges might be infinitely thin; if incapable of extension, the bottom ones might be indefinitely reduced. If it offered equal resistance to tension and compression, the neutral axis would occupy the centre of the beam, and the top and bottom flanges would require to be of equal strength.

We are indebted to Mr. Eaton Hodgkinson for the publication* of a valuable set of experiments conducted by him, having for their object the determination of the position of the neutral axis in cast-iron beams. The result of his

* Experimental Researches on the Strength and other Properties of Cast Iron, 8vo, 1846. WEALE.

experiments is, that in cast-iron rectangular beams, the position of the neutral axis at the time of fracture is at about one-seventh of the whole depth of the beam below its upper surface. Hence, in girders with flanges, the thickness of the bottom flanges should be six times that of the upper ones (supposing them to be of the same width), in order to obtain the greatest strength with the least metal. Practically it would be almost impossible to cast a beam thus proportioned, and, therefore, the top flanges are made of the same thickness, or nearly so, as the bottom ones, but of a less width, so as to contain the same relative quantity of metal, disposed in a more convenient form for casting (fig. 75).

The difficulty of making sound castings where the parts are of unequal thickness also renders it necessary to make the thickness of the middle rib nearly equal to that of the flanges.

207. To calculate the strength of a cast-iron beam, the sectional area of whose top flanges is 1-6 of that of the bottom ones, we must find that of a rectangular beam of the same extreme depth and width, and deduct from it the resistance of the portions omitted between the top and bottom flanges (fig. 75).

If we call the whole width of the bottom of the beam, W, the sum of the widths of the two bottom flanges, w, the whole depth of the beam, D, and the vertical distance between the flanges, d (on the supposition that the top flanges are of the same widths as the bottom ones, and 1-6 of their thickness, as shown by the dotted lines in fig. 78), the distance between the supports, l, the strength of the material, s, and if the weight required to break a beam when loosely supported at the ends and loaded in the middle be called x,

$$\text{Then } x = \frac{(\mathrm{W\,D}^2 - w\,d^2)\ 4\,s}{l},$$

and if we take the length in feet and the other dimensions

in inches, and call $s = 560$ lbs., which is not too much for the best Staffordshire irons ; then

$4\ s = 2{,}240$ lbs. $= 1$ ton ; and therefore $\dfrac{W\,D^2 - w\,d^2}{l} =$ breaking weight in tons.

The value of d in this rule will be D — 7-6 of the thickness of the bottom flanges, and so long as the sectional area of the top flanges is more than 1-6 of that of the bottom ones*, the rule may be applied to girders of variously proportioned flanges, as the additional strength gained by increasing the size of the top flanges beyond the proportion here named is very small in proportion to the metal used, and, in neglecting to take it into account, we are sure to err on the safe side.

208. It must not be supposed, that because increasing the thickness of the top flanges does not materially increase the resistance to vertical pressure, it is on that account useless : on the contrary, where a beam is of considerable depth in proportion to the widths of the bottom flanges, it will often be desirable to make the top flanges more than 1-6 of the bottom ones, in order to prevent the girder from twisting laterally, and to increase the resistance to any side thrust to which it may be exposed from brick arches or otherwise.

209. In practice, it is not desirable to load iron girders beyond $\frac{1}{3}$ of their ultimate strength, and they should be *proved* before use by loading them to this extent or a little more, but care should be taken never to let the proof exceed $\frac{1}{2}$ the breaking weight, as a greater load than this strains and distresses the metal, making it permanently weaker. The ultimate strength of a girder of the usual proportions may be approximately ascertained from its deflexion under proof

* It must be remembered that in making the top flanges narrower than the bottom ones for convenience of casting, as the bulk of the metal is brought nearer to the neutral axis by so doing, the sectional area of the top flanges must be rather more than 1-6 of that of the bottom ones, in order to keep the position of the neutral axis the same as in a rectangular beam.

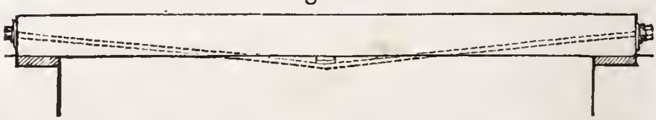
on the assumption that a load equal to half the breaking weight will cause a deflection of 1-480th of its length.

210. *Trussed Timber Beams.*—Timbers exposed to severe strain require to be *trussed* with iron, and this may be done in two ways: 1st, by inserting cast-iron struts, as in fig. 76, thus placing the whole, or nearly the whole, of the wood-

Fig. 76.

work in a state of tension; 2d, by wrought-iron tension rods, as in fig. 77, which take the whole of the tension,

Fig. 77.



whilst the timber is thrown entirely into compression. The latter mode of trussing is now very extensively used in strengthening the carriages of traveling cranes and for similar purposes; and, by its use, a balk of timber which will barely support its own weight safely without assistance, may be made to carry a load of many tons without sensible deflection.

STRENGTH OF STORY-POSTS AND CAST-IRON PILLARS.

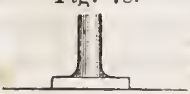
211. When a piece of timber, whose length is not less than 8 or 10 times its diameter, is compressed in the direction of its length, as in the case of a wooden story-post supporting a bressummer, it will give way if loaded beyond a certain point, not by crushing, but by bending, and will ultimately be destroyed by the cross-strain, just as a horizontal beam would be by vertical pressure applied at right angles to the

fibres. The rules for determining the dimensions of a piece of timber to support a given weight without sensible flexure are very complicated, and are of little practical value, as they depend upon the condition that the pressure is exactly in the direction of the axis of the post—a condition rarely fulfilled in practice.

212. Wooden story-posts have been to a great extent superseded by the use of cast-iron pillars, which possess great strength with a small sectional area, and are on that account particularly well adapted to situations where it is of consequence to avoid obstructing light, as in shop-fronts.

In determining the design of a cast-iron pillar, whose length is 20 or 30 times its diameter, two points have to be considered: 1st, the liability to flexure; 2d, the risk of the ends being crushed by the load not acting in the direction of the axis of the pillar.

Fig. 78.



The resistance to flexure is greatly increased by enlarging the bearing surface at the ends of the pillar, as in fig. 78, which, on the other hand, increases the liability of the ends to fracture, in the event of the load being thrown on the side instead of on the centre of the column, by any irregular settlement of the building. The judicious architect will, therefore take a mean course, swelling out the capitals and bases of his cast-iron pillars enough to prevent their shafts from bending, but at the same time avoiding any thin flanges or projections, which might be liable to be broken. No theoretical rule for determining the proportions of a cast-iron pillar depending on the weight to be supported can be depended on in practice. The real measure of the strength of a cast-iron story post must be the power of resisting any lateral force which may be brought against it; and as a slight side blow will suffice to fracture a pillar which is capable of supporting a vertical pressure of very many tons, we have only to make

sure of the lateral strength, and we are quite certain to be on the safe side as regards any vertical pressure which it may have to sustain.

213. Besides the above cases of transverse strain, there are others arising from irregular settlements, which are amongst the greatest difficulties with which the builder has to contend. Thus, to take a familiar instance, the window sills of a dwelling-house are often broken by the settlement of the brick-work being greater in the piers than under the sills, from the greater pressure on the mortar joints; and this will take place with a difference of settlement which can scarcely be detected, even by careful measurement*. We need not here enlarge on this subject, as we have several times in the preceding pages had occasion to notice both the causes of irregular settlement, and the precautions to be taken for its prevention.

The strength of materials to resist *torsion* or twisting, as in the case of a driving shaft, is an important consideration in the construction of machinery, but is of little consequence in the erection of buildings, and therefore need not be noticed in these pages.

* The reader need scarcely be told that a careful builder will always defer *pinning up* his sills until some time has been allowed for the settlement of the brick-work, but this will not always prevent ultimate fracture.

SECTION IV.

USE OF MATERIALS.

EXCAVATOR.

214. The digging required for the foundations of common buildings usually forms part of the business of the bricklayer, and is paid for at per cubic yard, according to the depth of the excavation, and the distance to which the earth has to be wheeled ; this being estimated by the *run* of 20 yards.

In large works, which require coffer-dams and pumping apparatus to be put down before the ground can be got out for the foundations, the work assumes a different character, and is paid for accordingly ; the actual excavation being only a small item of the total cost compared with those of dredging, piling, puddling, shoring, pumping, &c.

The workmen required for the construction of coffer-dams and similar works are laborers of a superior class, accustomed to the management of pile-engines and tackle, and competent to the execution of such rough carpenter's work as is required in timbering large excavations.

BRICKLAYER.

215. The business of a bricklayer consists in the execution of all kinds of work in which brick is the principal material ; and in London it always includes tiling and paving with bricks or tiles. Where undressed stone is much used as a building material, the bricklayer executes this kind of work also, and in the country, the business of the plasterer is often united with the above named branches.

216. The tools of the bricklayer are the *trowel*, to take up and spread the mortar, and to cut bricks to the requiste length: the *brick axe*, for shaping bricks to any required bevel; the *tin saw*, for making incisions in bricks to be cut with the axe, and a *rubbing-stone*, on which to rub the bricks smooth after being roughly axed into shape. The *jointer* and the *jointing-rule* are used for *running* the centres of the mortar-joints. The *raker*, for raking out the mortar from the joints of old brick-work previous to re-pointing. The *hammer*, for cutting chases and splays. The *banker* is a piece of timber about 6 feet long, raised on supports to a convenient height to form a table on which to cut the bricks to any required gauge, for which *moulds* and *bevels* are required. The *crowbar*, *pick-axe*, and *shovel* are used in digging out the foundations, and the *rammer* in punning the ground round the footings, and in rendering the foundation firm where it is soft by beating or ramming.

To set out the work and to keep it true, the bricklayer uses the *square*, the *level*, and the *plumb-rule*; for circular or battering work he uses *templets* and *battering-rules*; *lines* and *pins* are used to lay the courses by; and *measuring-rods* to take dimensions. When brick-work has to be carried up in conjunction with stone-work, the height of each course must be marked on a *gauge-rod*, that the joints of each may coincide.

217. The bricklayer is supplied with bricks and mortar by a laborer, who carries them in a *hod*. The laborer also makes the mortar, and builds and strikes the scaffolding.

218. The bricklayer's scaffold is constructed with *standards*, *ledgers*, and *putlogs*. The standards are poles, from 40 to 50 ft. long, and 6 or 7 in. diameter at the butt ends, which are fimly bedded in the ground. When one pole is not sufficently long, two are lashed together, top and butt, the lashings being tightened with wedges. The ledgers are horizontal poles placed parallel to the walls, and lashed to

the standards for the support of the putlogs. The putlogs are cross pieces, usually made of birch, and about 6 ft. long, one end resting in the wall, the other on a ledger. On the putlogs are placed the scaffold boards, which are stout boards hooped at the ends to prevent them from splitting.

A bricklayer and his laborer will lay in a single day about 1000 bricks, or about two cubic yards.

The tools required for tiling are—the *lathing-hammer*, with two gauge marks on it, one at 7, and the other at 7½ inches; the *iron lathing staff*, to clinch the nails; the *trowel*, which is longer and narrower than that used for brick-work; the *bosse*, for holding mortar and tiles, with an iron hook to hang it to the laths or to a ladder; and the *striker*, a piece of lath about 10 in. long, for clearing off the superfluous mortar at the feet of the tiles.

219. Brick-work is measured and valued by the rod, or by the cubic yard, the price including the erection and use of scaffolding, but not centering to arches, which is an extra charge.

Bricknogging, pavings, and facings, by the superficial yard.

Digging and steining of wells and cesspools by the foot in depth, according to size, the price increasing with the depth.

Plain tiling and pantiling are valued per square of 100 feet superficial.

MASON.

220. The business of the mason consists in *working* the stones to be used in a building to their required shape, and in *setting* them in their places in the work. Connected with the trade of the mason are those of the *Stonecutter*, who *hews* and cuts large stones roughly into shape preparatory to their being *worked* by the mason, and of the *Carver*, who executes the ornamental portions of the stone-work of a building, as enriched cornices, capitals, &c.

221. Where the value of stone is considerable, it is sent from the quarry to the building in large blocks, and cut into slabs and scantlings of the required size with a stone-mason's saw, which differs from that used in any other trade in having no teeth. It is a long thin plate of steel, slightly jagged on the bottom edge, and fixed in a frame ; and, being drawn backwards and forwards in a horizontal position, cuts the stone by its own weight. To facilitate the operation, a heap of sharp sand is placed on an inclined plane over the stone, and water allowed to trickle through it, so as to wash the sand into the saw-cut. Of late years machinery worked by steam-power has been used for sawing marble into slabs to a very great extent, and has almost entirely superseded manual labor in this part of the manufacture of chimney-pieces.

Some freestones are so soft as to be easily cut with a toothed saw worked backwards and forwards by two persons.

The harder kinds of stones, as granites and gritstones, are brought roughly into shape at the quarry, with an axe or a scappling hammer, and are then said to be *scappled.*

222. The tools used by the mason for cutting stone consist of the *mallet* and *chisels* of various sizes. The mason's mallet differs from that used by any other artisan, being similar to a dome in contour, excepting a portion of the broadest part, which is rather cylindrical ; the handle is short, being only sufficiently long to enable it to be firmly grasped.

In London the tools used to work the faces of stone are the *point,* which is the smallest description of chisel, being never more than a quarter of an inch broad on the cutting edge ; the *inch tool;* the *boaster,* which is 2 in. wide ; and the *broad tool,* of which the cutting edge is 3½ in. wide. The tools used in working mouldings and in carving are of various sizes, according to the nature of the work.

Besides the above cutting tools the mason uses the

banker or bench, on which he places his stone for convenience of working, and *straight edges, squares, bevels,* and *templets,* for marking the shapes of the blocks, and for trying the surfaces as the work proceeds. Any angle greater or less than a right angle is called a bevel angle, and a *bevel* is formed by nailing two straight edges together at the required angle; a *bevel square* is a square with a shifting stock which can be set to any required bevel. A templet is a pattern for cutting a block to any particular shape; when the work is moulded, the templet is called a *mould.* Moulds are commonly made of sheet zinc, carefully cut to the profile of the mouldings with shears and files.

For setting his work in place the mason uses the *trowel, lines, and pins,* the *square* and *level,* and *plumb,* and *battering rules,* for adjusting the faces of upright and battering walls.

223. The mason's scaffold is double, that is, formed with two rows of standards, so as to be totally independent of the walls for support, as putlog holes are inadmissible in masonry.

During the last ten years the construction of scaffolds with round poles lashed with cords has been entirely superseded in large works by a system of scaffolding of square timbers connected by bolts and dog irons.

The hoisting of the materials is performed from these scaffolds by means of a traveling crane, which consists of a double traveling carriage running on a tramway formed on stout sills laid on the top of two parallel rows of standards. The crab-winch is placed on the upper carriage, and, by means of the double motion of the two carriages, can be brought with great ease and precision over any part of the work lying between the two rows of standards.

The facilities which are afforded by these scaffolds and traveling cranes for moving heavy weights over large areas, have led to their extensive adoption, not only in the erection of buildings, but on landing wharfs, masons and ironfound-

ers' yards, and similar situations, where a great saving of time and labor is effected by their use.

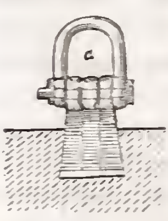
224. The movable derrick crane is also much used in setting mason's work. It consists of a vertical post supported by two timber backstays, and a long movable jib or derrick hinged against the post below the gearing.

By means of a chain passed from a barrel over a pully at the top of the post, the derrick can be raised almost to a vertical, or lowered to an almost horizontal position, thus enabling it to command every part of the area of a circle of a radius nearly equal to the length of the derrick. This gives it a great advantage over the old gibbet crane, which only commands a circle of a fixed radius, and the use of which entails great loss of time from its constantly requiring to be shifted as the work proceeds.

225. In hoisting blocks of stone they are attached to the tackle by means of a simple contrivance called a *lewis*, which is shown in fig. 79.

A tapering hole having been cut in the upper surface of the stone to be raised, the two side pieces of the lewis are inserted and placed against the sides of the hole; the centre parallel piece *a* is then inserted and secured in its place by a pin passing through all three pieces, and the stone may then be safely hoisted, as it is impossible for the lewis to draw out of the hole. By means of the lewis, in a slightly altered form from that here shown, stones can be lowered and set under water without difficulty, the lewis being disengaged by means of a line attached to the parallel piece; the removal of which allows the others to be drawn out of the mortice.

Fig. 79.

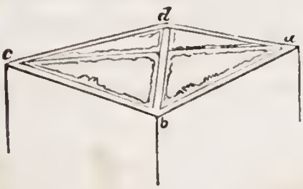


226. In stone-cutting, the workman forms as many plane faces as may be necessary for bringing the stone into the

required shape, with the least waste of material and labor, and on the plane surfaces so formed applies the moulds to which the stone is to be worked

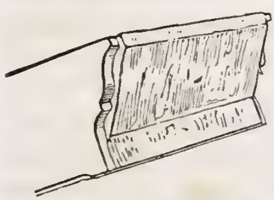
To form a plane surface, the mason first knocks off the superfluous stone along one edge of the block, as *a*, *b* (fig. 80), until it coincides with a straight edge throughout its whole length; this is called a *chisel draught.* Another chisel draught is then made along one of the adjacent edges as *b*, *c*, and the ends of the two are connected by another draught, as *a c;* a fourth draught is then sunk across the last, as *b*, *d*, which gives another angle point *d*, in the same plane with *a b*, and *c*, by which the draughts *d a* and *a c* can be formed; and the stone is then knocked off between the outside draughts until a straight edge coincides with the surface in every part.

Fig. 80.



To form cylindrical or moulded surfaces curved in one direction only, the workman sinks two parallel draughts at the opposite end of the stone to be worked, until they coincide with a mould cut to the required shape, and afterwards works off the stone between these draughts, by a straight edge applied at right angles to them (fig. 81).

Fig. 81.



The formation of conical or spherical surfaces is much less simple, and require a knowledge of the scientific operations of stone-cutting, a description of which would be unsuited to the elemetary character of these pages.

227. The finely-grained stones are usually brought to a smooth face, and rubbed with sand to produce a perfectly even surface.

In working soft stones, the surface is brought to a smooth face with the *drag*, which is a plate of steel, indented on the edge like the teeth of a saw, to take off the marks of the tools employed in shaping it.

The harder and more coarsely grained stones are generally *tooled*, that is, the marks of the chisel are left on their face. If the furrows left by the chisel are disposed in regular order, the work is said to be *fair-tooled*, but if otherwise, it may be *random-tooled* or *chiseled* or *boasted* or *pointed*. If the stones project beyond the joints, the work is said to be *rusticated*.

Granite and gritstone are chiefly worked with the scappling hammer. In massive erections, where the stones are large, and a bold effect is required, the fronts of the blocks are left quite rough, as they come out of the quarry, and the work is then said to be *quarry pitched*.

Many technical terms are used by quarrymen and others engaged in working stone ; but they need not be inserted here, as they are mostly confined to particular localities beyond which they are little known, or perhaps bear a different signification.

228. When the mason requires to give to the joints of his work greater security than is afforded by the weight of the stone and the adhesion of the mortar, he makes use of *joggles*, *dowels*, and *cramps*.

Stones are said to be joggled together when a projection is worked out on one stone to fit into a corresponding hole or groove in the other (*see* fig. 82). But this occasions great labor and waste of stone, and *dowel-joggles* are chiefly made use of, which are hard pieces of stone, cut to the required size, and let into corresponding mortices in the two stones to be joined together.

Fig. 82.

Dowels are pins of wood or metal used to secure the joints of stone-work in exposed situations, as copings, pin-

nacles, &c. The best material is copper; but the expense of this metal causes it to be seldom used. If iron be made use of, it should be thoroughly thinned to prevent oxidation, or it will, sooner or later, burst and split the work it is intended to protect.

Dowels are often secured in their places with lead poured in from above, through a small channel cut in the side of the joint for that purpose; but a good workman will eschew lead, which too often finds his way into bad work, and will prefer trusting to very close and workmanlike joints, carefully fitted dowels, and fine mortar; dowels should be made tapering at one end, which ensures a better fit, and renders the setting of the stone more easy for the workman.

Iron cramps are used as fastenings on the tops of copings, and in similar situations; but they are not to be recommended, as they are very unsightly, and, if they once become exposed to the action of the atmosphere, are powerfully destructive agents. Cast iron is, however, less objectionable than wrought iron for this purpose.

229 In measuring mason's work, the cubic content of the stone is taken as it comes to the *banker*, without deduction for subsequent waste.

If the scantlings are large, an extra price is allowed for hoisting.

The labor in working the stone is charged by the superficial foot, according to the kind of work, as plain work, sunk work, moulded work, &c

Pavings landings, &c., and all stones less than three in. thick, are charged by the superficial foot.

Copings, curbs, window sills, &c., are charged per lineal foot.

Cramps, dowels, mortice holes, &c., are always charged separately.

The remuneration of a stone-carver is dependent on his talent, and the kind of work he is engaged upon.

CARPENTER.

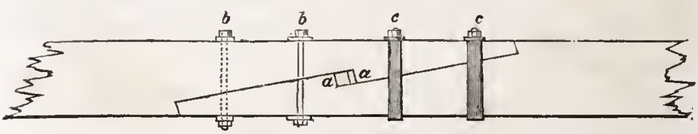
230. The business of the carpenter consists in framing timbers together, for the construction of roofs, partitions, floors, &c.

231. The capenter's principal tools are the axe, the adze, the saw, and the chisel, to which may be added the chalk, line, plumb-rule, level, and square. The work of the carpenter does not require the use of the plane, which is one of the principal tools of the joiner, and this forms the principal distinction between these trades, the carpenter being engaged in the rough frame-work, and the joiner on the finishings and decorations of buildings.

232. The principles of framing have been already fully described in the 1st section of this work, and we shall, therefore, confine our remarks on the operations of the carpenter to a description of the principal joints made use of in framing.

Timbers that have to be joined in the direction of their length, are *scarfed*, as shown in fig. 83 ; the double wedges. *a a*, serve to bring the timbers *home*, when they are secured,

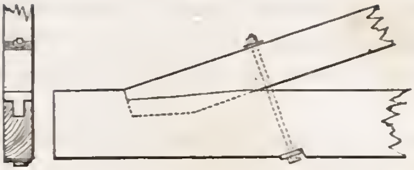
Fig. 83.



either by bolts, as shown at *b b* or by straps, as at *c c*, the latter being the most perfect and the most expensive fastening.

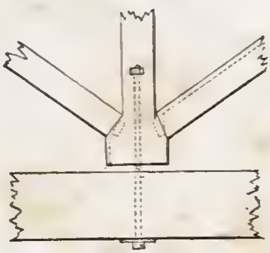
Fig. 84 shows the manner of connecting the foot of a principal rafter with a tie-beam. The bolt here shown keeps

Fig. 84.



the rafter in its place, and prevents it from slipping away from the abutment cut for it, which, by throwing the thrust on the tenon, would probably split it. The end of the rafter should be cut with a square butt, so that the shrinkage of the timber will not lead to any settlement.

Fig. 85.



The connection of the foot of a king-post with the tie-beam to be suspended from it is shown in fig. 85.

The king-post should be cut somewhat short, to give the power of screwing up the framing after the timber has become fully seasoned. The tie-beam may be suspended from the king-post, either by a bolt, as shown, or by a strap passed round the tie-beam and secured by iron wedges or cotters, passing through a hole in the king-post ; this last is the more perfect, but at the same time the more expensive of the two methods.

Fig. 85 also shows the manner in which the feet of the struts butt upon the king-post. They are slightly tenoned to keep them in their places. The ends of a strut should be cut off as nearly square as possible, otherwise, when the timber shrinks, which it always does, more or less, the thrust is thrown upon the edge only, which splits or crushes under the pressure, and causes settlement.

This is shown out by the dotted lines on the right-hand side of the cut. The dotted lines on the opposite side of the

figure show a similar effect, produced by the shrinking of the king-post, for which there is no preventive but making it of oak, or some other hard wood. The same observations apply to the connections of the principal rafters with the top of the king-post, which are managed in a precisely similar manner.

In figures 86, 87, and 88, are shown different methods

Fig. 86.

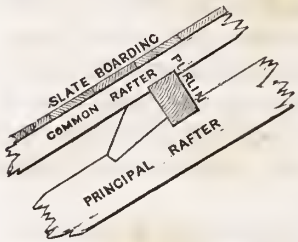
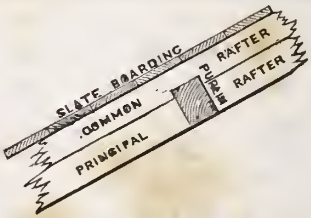
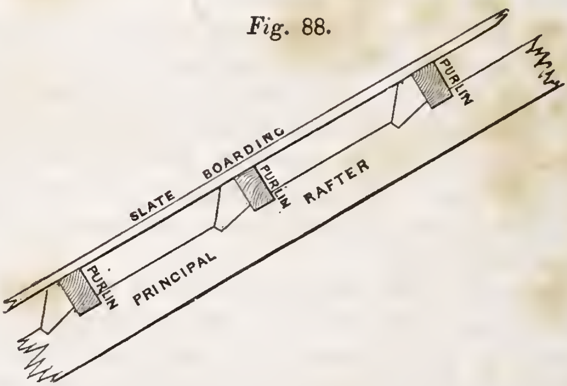


Fig. 87.



of fixing purlins, which are sufficiently explained by the figures to need no further description.

Fig. 88.



In figures 44, 45, 46, and 47, are shown the modes of framing the ends of binding joists into girders, and of connecting the ceiling joists with the binders; and as these have been already described under the head of "Floors," it is unnecessary here to say anything further on the subject.

As a general rule, all timbers should be notched down to those on which they rest, so as to prevent their being moved either lengthways or sideways. Where an upright post has to be fixed between two horizontal sills, as in the case of the uprights of a common framed partition, it is simply tenoned into them, and the tenons secured with oak pins driven through the cheeks of the mortice.

233. The carpenter requires considerable bodily strength for the handling of the timbers on which he has to work; he should have a knowledge of mechanics, that he may understand the nature of the strains and thrusts to which his work is exposed, and the best method of preventing or resisting them; and he should have such a knowledge of working drawings as will enable him, from the sketches of the architect, to set out the *lines* for every description of centering and framing that may be entrusted to him for execution.

234. In measuring carpenters' work the tenons are included in the length of the timber: this is not the case in joiners' work, in which they are allowed for in the price.

The labor in framing, roofs, partitions, floors, &c., is either valued at per square of 100 superficial feet, and the timber charged for separately, or the timber is charged as "fixed in place," the price varying according to the labor on it, as "cube fir in bond," "cube fir framed," "cube fir wrought and framed," &c. For shoring $\frac{1}{3}$ of the value of the timber is allowed for use and waste.

JOINER.

235. The work of the joiner consists in framing and *joining* together the wooden finishings and decorations of buildings, both internal and external, such as floors, staircases, framed-partitions, skirtings, solid door and window frames, hollow or *cased* window frames, sashes and shutters, doors, columns and entablatures, chimney-pieces, &c., &c.

The joiner's work requires much greater accuracy and finish than that of the carpenter, and differs materially from it in being brought to a smooth surface with the plane wherever exposed to view, whilst in carpenters' work the timber is left rough as it comes from the saw.

236. The joiner uses a great variety of tools ; the principal *cutting* tools are *saws*, *planes*, and *chisels*.

Of saws there are many varieties, distinguished from each other by their shape and by the size of the teeth.

The *ripper* has 8 teeth in 3 inches ; the *half-ripper* 3 teeth to the inch ; the *hand saw* 15 teeth in 4 inches ; the *panel saw* 6 teeth to the inch.

The *tenon saw*, used for cutting tenons, has about 8 teeth to the inch, and is strengthened at the back by a thick piece of iron, to keep the blade from buckling. The *sash saw* is similar to the tenon saw, but is backed with brass instead of iron, and has 13 teeth to the inch. The *dovetail saw* is still smaller, and has 15 teeth to the inch.

Besides the above, other saws are used for particular purposes, as the *compass saw*, for cutting circular work, and the *key-hole saw*, for cutting out small holes. The *carcase saw* is a large kind of dovetail saw, having about 11 teeth to an inch.

237. Planes are also of many kinds ; those called *bench planes*—as the *jack plane*, the *trying plane*, the *long plane*, the *jointer*, and the *smoothing plane*, are used for bringing the stuff to a plane surface. The jack plane is about 18 inches long, and is used for the roughest work. The trying plane is about 22 in. long, and used after the jack plane for *trying up*, that is, taking off shavings the whole length of the stuff ; whilst in using the jack plane the workman stops at every arm's-length. The *long plane* is 2 ft. 3 in. long, and is used when a piece of stuff is to be tried up very straight. The

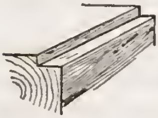
MONUMENT OF PHILOPAPPUS

page 276.

jointer is 2 ft. 6 in. long, and is used for trying up or *shooting* the *joints*, in the same way as the trying plane is used for trying up the *face* of the stuff. The *smoothing plane* is small, being only 7½ in. long, and is used on almost all occasions for cleaning off finished work.

Rebate planes are used for sinking *rebates* (*see* fig. 89), and vary in their size and shape according to their respective uses. Rebate planes differ from bench planes in having no handle rising out of the stock, and in discharging their shavings at the side. Amongst the rebate planes may be mentioned the *moving fillister* and the *sash fillister*, the uses of which will be better understood by inspection than from any description.

Fig. 89.



Moulding planes are used for *sticking* mouldings, as the operation of forming mouldings with the plane is called. When mouldings are worked out with chisels instead of with planes, they are said to be worked *by hand*. Of the class of moulding planes, although kept separate in the tool chest, are *hollows* and *rounds* of various sizes.

There are other kinds of planes besides the above ; as the *plough*, for sinking a groove to receive a projecting tongue ; the *bead plane*, for sticking beads ; the *snipe bill*, for forming quirks ; the *compass plane* and the *forkstaff plane*, for forming concave and convex cylindrical surfaces. The shape and use of these and many other tools used by the joiner will be better understood by a visit to the joiner's shop than by any verbal description.

238. Chisels are also varied in their form and use. Some are used merely with the pressure of the hand, as the *paring chisel ;* others, by the aid of the mallet, as the *socket chisel**, for cutting away superfluous stuff ; and the *mortice chisel*, for cutting mortices. The *gouge* is a curved chisel.

* Named from the iron forming a socket to receive a wooden handle.

239. The joiner uses a great variety of boring tools, as the *brad-awl*, *gimlet*, and *stock and bit*. The last form but one tool, the *stock* being the handle, to the bottom of which may be fitted a variety of steel bits of different bores and shapes, for boring and widening out holes in wood and metal, as *countersinks*, *rimers*, and *taper shell bits.*

240. The *screw driver*, *pincers*, *hammer*, *mallet*, *hatchet*, and *adze*, are too well known to need description.

The *gauge* is used for drawing lines on a piece of stuff parallel to one of its edges.

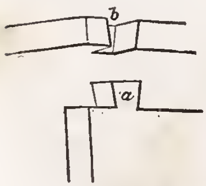
The *bench* is one of the most important of the joiner's implements. It is furnished with a vertical *sideboard*, perforated with diagonal ranges of holes, which receive the *bench pin* on which to rest the lower end of a piece of stuff to be planed, whilst the upper end is firmly clamped by the *bench screw.*

The *mitre box* is used for cutting a piece of stuff to a *mitre* or angle of 45 degrees with one of its sides.

The joiner uses for setting out and fixing his work—the straight edge, the square, the bevel or square with a shifting blade, the mitre square, the level, and the plumb rule.

In addition to the tools and implements above enumerated, the execution of particular kinds of work require other articles, as cylinders, templets, cramps, &c., the description of which would unnecessarily extend the limits of this volume.

Fig. 90.

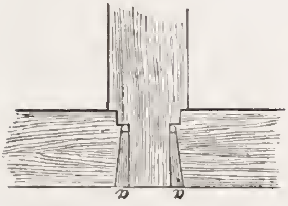


The principal operations of the joiner are sawing, planing, dovetailing, mortising, and scribing.

The manner of forming a *dovetail* is shown in fig 90. The projecting part, *a*, is called the *pin*, and the hole to receive it is called the *socket.*

Mortising is shown in fig. 91; the projecting piece is called the *tenon*, and the hole formed to receive it the *mortice*. The tenon is sometimes *pinned* in its place with oak pins driven through the cheeks of the mortice; but in forming doors, shutters, &c., the tenon is secured with tapering wedges driven into the mortice, which is cut slightly wider at the top than at the bottom, the adhesion of the glue with which the wedges are first rubbed over, making it impossible for the tenon afterwards to draw out of its place.

Fig. 91.



241 Joints in the length of the stuff may be either square, as at *a*, fig. 92, or rebated, as at *b*, or grooved and tongued,

Fig. 92.

as at *c*, or grooved on each edge and a tongue let in, as at *d*.

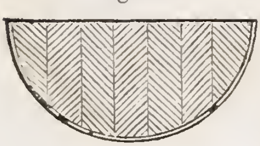
242. *Scribing* is the drawing on a piece of stuff the exact profile of some irregular surface to which it is to be made to fit: this is done with a pair of compasses, one leg of which is made to travel the irregular surface, the other to *describe* a line parallel thereto along the edge of the stuff to be cut.

243. In the execution of circular, or, as it is termed, *sweep work*, there are four different methods by which the stuff can be brought to the required curve:—

1st. It may be steamed and bent into shape.

2nd. It may be glued up in thicknesses, as shown in fig. 93, which must, when thoroughly dry, be planed true, and, if not to be painted, covered with a thin veneer bent round it.

Fig. 93.



3rd. It may be formed in thin thicknesses, as shown in fig. 94,

bent round and glued up in a mould. This may be considered the most perfect of all the methods in use.

Fig. 94.

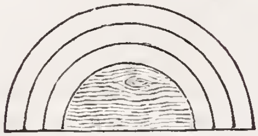
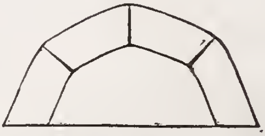


Fig. 95.



Lastly. It may be formed by sawing a number of notches on one side, as shown in fig. 95, by which means it becomes easily bent in that direction, but the curve produced by this means is very irregular, and it is an inferior mode of execution compared to the others.

When a number of boards are secured together by cross-pieces or *ledges* nailed or screwed at the back, the work is said to be *ledged* (*see* fig. 96). Ledged work is used for common purposes, as cellar doors, outside shutters, &c.

Fig. 96

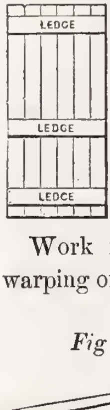
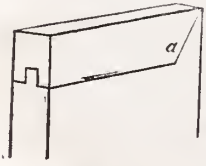


Fig. 97.

Framed work (fig. 97), consists of *styles* and *rails* mortised and tenoned together, and filled in with pannels, the edges of which fit in grooves cut in the styles and rails.

Work is said to be *clamped* when it is prevented from warping or splitting by a rail at each end, as in fig. 98; if the ends of the rail are cut off, as shown at *a*, it is said to be mitre clamped.

Fig 98.



There are two ways of laying floors practised by joiners. In laying what is called a *straight joint* floor, from the joints between the boards running in an unbroken line from wall to wall, each board is laid down and nailed in succession, being first forced firmly against the one last laid with a flooring cramp.

Folding floors are laid by nailing down first every fifth board rather closer together than the united widths of four boards, and forcing the intermediate ones into the space left for them by jumping over them ; this method of laying floors is resorted to when the stuff is imperfectly seasoned and is expected to shrink, but it should never be allowed in good work.

The narrower the stuff with which a floor is laid the less will the joints open, on account of the shrinkage being distributed over a greater number of joints.

The floor boards may be nailed at their edges and grooved and tongued or dowelled, if it be wished to make a very perfect floor. Dowelling is far superior to grooving and tonguing, because the cutting away the stuff to receive the tongue greatly weakens the edges of the joint, which are apt to curl.

244. Glue is an article of great importance to the joiner ; the strength of his work depending much upon its adhesive properties.

The best glue is made from the *skins* of animals ; that from the *sinewy* or *horny* parts being of inferior quality. The strength of the glue increases with the age of the animals from which the skins are taken.

Joiners' work is measured by the superficial foot, according to its description.

Floors by the square of 100 superficial feet

Handrails, small mouldings, water-trunks, and similar articles, per lineal foot.

Cantilevers, trusses, cut-brackets, scrolls to handrails, &c., are valued per piece.

Ironmongery is charged for with the work to which it is attached ; the joiner being allowed 20 per cent. profit upon the prime cost.

The principal articles of *ironmongery* used in a building consist of *nails* and *screws*, *sash pullies*, *bolts*, *hinges*, *locks*,

latches, and *sash shutter furniture*, besides a great variety of miscellaneous articles, which we have not space to enumerate.

Of the different kinds of hinges may be mentioned *hook* and *eye hinges*, for gates, coach-house doors, &c.; *butts* and *back-flaps*, for doors and shutters ; *crosss-garnets* of H form, which are used for hanging ledged doors, and other inferior work ; ⊢ and H— hinges, whose name is derived from their shape ; and *parliament* hinges.

Besides these are used *rising butts*, for hanging doors to rise over a carpet, or other impediment ; *projecting butts*, used when some projection has to be cleared, and *spring hinges* and *swing centres* for self-shutting doors.

The variety of locks now manufactured is almost infinite. We may mention the *stock lock*, cased in wood, for common work. *Rim locks* which have a metal case or rim, and are attached to one side of a door : they should not be used when a door has sufficient thickness to allow of a mortice lock, as they often catch the dresses of persons passing through the doorway. *Mortice locks*, as the name implies, are those which are morticed to the thickness of a door.

The handles and escutcheons are called the *furniture* of a lock, and are made of a great variety of materials, as brass, bronze, ebony, ivory, glass, &c.

Of latches, there are the common *thumb latch*, the *bow latch*, with brass knobs, the brass *pulpit latch* and the *mortice latch*.

The *sawyer* is to the carpenter and joiner what the stone-cutter is to the mason.

The *pit saw* is a large two-handed saw fixed in a frame, and moved up and down in a vertical direction, by two men, called the top-man and the pit-man; the first of whom stands on the timber that is to be cut, the other at the bottom of the saw pit. The timber is *lined out* with a chalk line on its upper surface, and the accuracy of the work depends mainly on the top-man keeping the saw to the line, whence the pro-

verbial expression *top sawer*, meaning one who directs any undertaking.

In sawing up deals and battens into thicknesses for the joiner's use, the parallelism of the cuts is of the utmost importance, as the operation of *taking out of winding*, a piece of uneven stuff, causes a considerable waste of material, and much loss of time.

Circular saws, moved by steam-power, are now much used in large establishments, timber yards, &c., and effect a great saving of labor over the use of the pit saw, where the timbers to be cut are not too heavy to be easily handled. The saw is mounted in the middle of a stout bench, furnished with guides, by means of which the stuff to be cut is kept in the required direction, whilst it is pushed against the saw, which is the whole of the manual labor required in the operation.

SLATER.

245. The business of the slater consists chiefly in covering the roofs of houses with slates, but it has of late years being very much extended by the general introduction of sawn slate, as a material for shelves, cisterns, baths, chimney-pieces, and even for ornamental purposes.

We propose here to describe only those operations of the slater which have reference to the covering of roofs.

246. Besides the tools which are in use among other artificers, the slater uses one peculiar to his trade called the *zax*, which is a kind of hatchet, with a sharp point at the back. It is used for trimming slates, and making the holes by which they are nailed in their places.

247. Slates are laid either on boarding or on narrow battens, from 2 to 3 inches wide, the latter being the more common method, on account of its being less expensive than the other.

The nails used should be either copper or zinc; iron nails,

though sometimes used, being objectionable, from their liability to rust.

Every slate should be fastened with two nails, except in the most inferior work.

The upper surface of a slate is called its *back*, the under surface the *bed* the lower edge the *tail*, the upper edge the *head.* The part of each course of slates exposed to view is called the *margin* of the course, and the width of the margin is called the *gauge.*

The *bond* or *lap* is the distance which the lower edge of any course overlaps the slates of the second course below, measuring from the nail-hole.

In preparing slates for use, the sides and bottom edges are trimmed, and the nail-holes punched as near the head as can be done, without risk of breaking the slate, and at a uniform distance from the tail.

The lap having been decided on, the guage will be equal to half the distance from the tail to the nail-hole, less the lap. Thus a countess slate, measuring 19 in. from tail to nail, if laid with a 3 in. lap, would show a margin of $\frac{19 \text{ in.} - 3 \text{ in.}}{2} =$ 8 in. (*See* figs. 99. 100.)

Fig. 99.

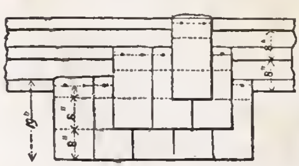
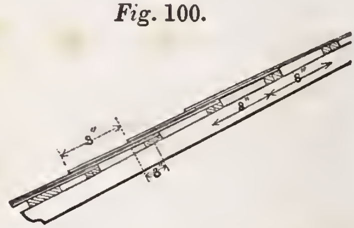


Fig. 100.



The battens are of course nailed on the rafters at the gauge to which the slate will work. If the slates are of different lengths, they must be sorted into sizes, and gauged accordingly, the smallest sizes being placed nearest the ridge. The lap should not be less than 2, and need not exceed 3 in.

It is essential to the soundness as well as the appearance of slaters' work, that the slates should all be of the same width, and the edges perfectly true.

The Welsh slates are considered the best, and are of a light sky blue color. The Westmoreland slates are of a dull greenish hue.

248. Slaters' work is measured by the square of 100 superficial feet, allowances being made for the trouble of cutting the slates at the hips, eaves, round chimneys, &c.

Slabs for cisterns, baths, shelves, and other sawn work, are charged per superficial foot, according to the thickness of the slab and the labor bestowed on the work..

Rubbed edges, grooves, &c., are charged per lineal foot.

Table of Sizes of Roofing Slates.

DESCRIPTION.	Size.				Average gauge in inches.	No. of squares 1200 will cover.	Weight per 1200 in tons.	No. required to cover one square.	No. of nails required to one square.
	Length.		Breadth.						
	ft.	in.	ft.	in					
Doubles . .	1	1	0	6	5½	2	¾	480	480
Ladies . . .	1	4	0	8	7	4½	1¼	280	280
Countesses	1	8	0	10	9	7	2	176	352
Duchesses	2	0	1	0	10½	10	3	127	254
Imperials .	2	6	2	0	a ton will cover 2¼ to 2½ squares.				
Rags and Queens	3	0	2	0					
Westmorelands, of various sizes.						do.	2		do.

Inch slab per superficial weighs 14 lbs.

PLASTERER.

249. The work of the plasterer consists in covering the brickwork and naked timber walls, ceilings, and partitions

with plaster, to prepare them for painting, papering, or distempering; and in forming cornices, and such decorative portions of the finishings of buildings as may be required to be executed in plaster or cement.

250. The plasterer uses a variety of tools, of which the following are the principal ones :—

The *drag* is a three-pronged rake, used to mix the hair with the mortar in preparing coarse stuff.

The *hawk* is a small square board for holding stuff on, with a short handle on the under side.

Trowels are of two kinds, the *laying and smoothing tool*, with which the first and the last coats are laid, and the *gauging trowel*, used for gauging fine stuff for cornices, &c. ; these are made of various sizes, from 3 to 7 in. long.

Of *floats*, which are used in *floating*, there are three kinds, viz., the *Derby*, which is a rule of such a length as to require two men to use it ; the *hand float*, which is used in finishing stucco ; and the *quirk float*, which is used in floating angles.

Moulds, for running cornices, are made of sheet copper, cut to the profile of the moulding to be formed, and fixed in a wooden frame.

Stopping and *picking out tools* are made of steel, 7 or 8 in. long, and of various sizes. They are used for modeling, and for finishing mitres and returns to cornices.

251. *Materials.—Coarse stuff*, or lime and hair, as it is usually called, is similar to common mortar, with the addition of hair from the tanners' yard, which is thoroughly mixed with the mortar by means of the drag.

Fine stuff is made of pure lime, slaked with a small quantity of water, after which, sufficient water is added to bring it to the consistence of cream.

It is then allowed to settle, and the superfluous water being poured off, it is left in a binn or tub to remain in a semifluid state until the evaporation of the water has brought

it to a proper thickness for use. In using fine stuff for setting ceilings, a small portion of white hair is mixed with it.

Stucco is made with fine stuff, and clean-washed sand. This is used for finishing work intended to be painted.

Gauged stuff is formed of fine stuff mixed with plaster of Paris, the proportion of plaster varying according to the rapidity with which the work is required to set. Gauged stuff is used for running cornices and mouldings.

Enrichments, such as pateras, centre flowers for ceilings, &c., are first modeled in clay, and afterwards cast of plaster of Paris in wax or plaster moulds. Papier maché ornaments also are much used, and have the advantage of being very light, and being easily and securely fixed with screws.

The variety of compositions and cements made use of by the plasterer is very great. Roman cement, Portland cement, and lias cement, are the principal ones used for coating buildings externally. Martin's and Keene's cements are well adapted for all internal plastering where sharpness, hardness, and delicate finish are required.

252. *Operations of Plastering.*—When brick-work is plastered, the first coat is called *rendering.*

In plastering ceilings and partitions, the first operation is *lathing.* This is done with *single, one and a half,* or *double* laths; these names denoting their respective thicknesses. Laths are made of wood: if hard wood, wrought iron nails are used, but cast iron may be employed with soft wood. The thickest laths are used for ceilings, as the strain on the laths is greater in a horizontal than in an upright position.

Pricking up is the first coat of plastering of course stuff upon laths; when completed, it is well scratched over with the end of a lath, to form a key for the next coat.

Laid work consists of a simple coat of coarse stuff over a wall or ceiling.

Two-coat work is a cheap description of plastering, in which the first coat is only roughed over with a broom, and afterwards *set* with fine stuff, or with gauged stuff in the better descriptions of work.

The laying on of the second coat of plastering is called *floating*, from its being *floated*, or brought to a plane surface with the float.

The operation of floating is performed by surrounding the surface to be floated with narrow strips of plastering, called screeds, brought perfectly upright, or level, as the case may be, with the level or plumb-rule ; thus, in preparing for floating a ceiling, nails are driven in at the angles, and along the sides, about 10 ft. apart, and carefully adjusted to a horizontal plane, by means of the level. Other nails are then adjusted exactly opposite to the first, at a distance of 7 or 8 in. from them. The space between each pair of nails is filled up with coarse stuff, and leveled with a hand float ; this operation forms what are called *dots.* When the dots are sufficiently dry, the spaces between the dots are filled up flush with coarse stuff, and floated perfectly true with a floating rule; this operation forms a *screed*, and is continued until the ceiling is surrounded by one continuous screed, perfectly level throughout. Other screeds are then formed, to divide the work into bays about 8 ft. wide, which are successively filled up flush, and floated level with the screeds.

The screeds for floating walls are formed in exactly the same manner, except that they are adjusted with the plumb-rule instead of the level.

After the work has been brought to an even surface with the floating rule, it is gone over with the hand float, and a little soft stuff, to make good any deficiencies that may appear.

The operation of forming screeds and floating work, which is not either vertical or horizontal, as a plaster floor laid with a fall, is analogous to that of taking the face of a stone cut of winding with chisel-drafts and straight edges in stone-

cutting ; the principle being in each case to find three points in the same plane, from which to extend operations over the whole surface.

Setting.—When the floating is about half dry, the setting or finishing coat of fine stuff is laid on with the smoothing trowel, which is alternately wetted with a brush and worked over with the smoothing tool, until a fine surface is obtained.

Stucco is laid on with the largest trowel, and worked over with the hand float, the work being alternately sprinkled with water, and floated until it becomes hard and compact, after which it is finished by rubbing it over with a dry stock brush.

The water has the effect of hardening the face of the stucco, so that, after repeated sprinklings and trowelings, it becomes very hard, and smooth as glass.

253. The above remarks may be briefly summed up as follows. The commonest kind of work consists of only one coat, and is called *rendering*, on brick-work, and *laying*, if on laths. If a second coat be added, it becomes two-coat work, as *render-set*, or *lath lay* and *set*. When the work is floated, it becomes three-coat work, and is *render*, *float*, and *set*, for brick-work, and *lath*, *lay*, *float*, and *set*, for ceilings and partitions ; ceilings being set with fine stuff, with a little white hair, and walls intened for paper with fine stuff and sand ; stucco is used where the work is to be painted.

Rough stucco is a mode of finishing staircases, passages, &c., in imitation of stone. It is mixed with a large proportion of sand, and that of a coarser quality than troweled stucco, and is not smoothed, but left rough from the hand float, which is covered with a piece of felt, to raise the grit of the sand, to give the work the appearance of stone.

Rough cast is a mode of finishing outside work, by dashing over the second coat of plastering, whilst quite wet, a layer of rough-cast, composed of well-washed gravel, mixed up with pure lime and water, till the whole is in a semifluid state.

Pugging is lining the spaees between floor joists with coarse stuff, to prevent the passage of sound, or between two stones, and is done on laths or rough boarding.

In the midland districts of England, reeds are much used instead of laths, not only for ceilings and partitions, but for floors, which are formed with a thick layer of coarse gauged stuff upon reeds. Floors of this kind are extensively used about Nottingham; and, from the security against fire afforded by the absence of wooden floors, Nottingham houses are proverbially fire-proof.

254. Plasterer's work is measured by the superficial yard; cornices by the superficial foot; enrichments to cornices by the lineal fool; and centre flowers and other decorations at per piece.

MEMORANDA.

Lathing.—One bundle of laths and 384 nails will cover 5 yards.

Rendering.—187½ yards require 1½ hundred of lime, 2 double loads of sand, and 5 bushels of hair.

Floating requires more labor, but only half as much material as rendering.

Setting.—375 yards require 1½ hundred of lime, and 5 bushels of hair.

Render set.—100 yards require 1½ hundred of lime, 1 double load of sand, and 4 bushels of hair. Plasterer, laborer, and boy, 3 days each.

Lath, lay, and *set.*—130 yards of lath, lay, and set, require 1 load of laths, 10,000 nails, 2½ hundred of lime, 1½ double load of sand, and 7 bushels of hair. Plasterer, laborer, and boy, 6 days each.

SMITH AND IRONFOUNDER.

255. The smith furnishes the various articles of wrought-iron work used in a building; as pileshoes, straps, screw-

bolts, dog-irons, chimney bars, gratings, wrought-iron railing, and wrought-iron balustrades for staircases. Wrought iron was formerly much used for many purposes, for which cast iron is now almost exclusively employed; the improvements effected in casting during the present century having made a great alteration in this respect.

The operations of the ironfounder have been described in Section II. of this volume, and therefore we have only here to enumerate some of the principal articles which are furnished by him.

Besides cast-iron columns, girders, and similar articles which are cast to order, the founder supplies a great variety of articles which are kept in store for immediate use; as cast-iron gratings, balconies, rain-water pipes and guttering, air traps, coal plates, stoves, stable fittings, iron sashes, &c.

Both wrought and cast-iron work are paid for by weight, except small articles kept in store for immediate use, which are valued per piece.

		lbs.
One cubic foot of	cast iron weighs about	450
Ditto	wrought ,,	475
Ditto	closely hammered	485

256. The *Coppersmith* provides and lays sheets of copper for covering roofs; copper gutters, and rainwater pipes; washing and brewing coppers; copper cramps and dowels for stonemasons' work; and all other copper work in a building; but the cost of the material in which he works prevents its general use; and the washing copper is frequently the only part of a building which requires the aid of this artificer. Sheet copper is paid for by the superficial foot, according to weight, and pipes and gutters per lineal foot; copper in dowels, bolts, &c., at per pound.

257. *Warming apparatus*, *steam* and *gas fittings*, and similar kinds of work, are put up by the mechanical engineer, who also manufactures a great variety of articles, which are

purchased in parts, and put together and fixed by the plumber, as pumps, taps, water-closet apparatus, &c.

258. The *bell-hanger* provides and hangs the bells required for communicating between the different parts of a building, and connects them with their *pulls*, or handles, by means of cranks and wires.

The action of the pull upon the bell should be as direct, and effected with as few cranks as possible ; and the cranks and wires should be concealed from view, both to protect them from injury, and on account of their unsightly appearance.

In all superior work, the wires are conducted along concealed tubes, fixed to the walls before the plasterer's work is commenced. The simplest way of arranging the wires is to carry them up in separate tubes to the roof, where they may all be conducted to one point, and brought down a chase in the walls to the part of the basement where the bells are hung, By this means very few cranks are required, and a broken wire can be replaced at any time without trouble.

259. Bell-hangers' work is paid for by the number of bells hung ; the price being determined by the manner in which the work is executed. The *furniture* to the pulls is charged in addition, at per piece.

PLUMBER.

260. The work of the plumber chiefly consists in laying sheet lead on roofs, lining cisterns, laying on water to the different parts of a building, and fixing up pumps and water closets.

261. The plumber uses but few tools, and those are of a simple character ; the greater number of them being similar to those used by other artificers, as *hammers*, *mallets*, *planes*, *chisels*, *gouges*, *files*, &c. The principal tool peculiar to the

trade of the plumber is the *bat*, which is made of beech, about 18 in. long, and is used for dressing and flattening sheet lead. For soldering also the plumber uses iron ladles, of various sizes, for melting solder, and *grozing irons*, for smoothing down the joints.

262. The sheet lead used by the plumber is either *cast* or *milled*, the former being generally cast by the plumber himself out of old lead taken in exchange ; whilst the latter, which is cast lead, flattened out between rollers in a flatting mill, is purchased from the manufacturer. Sheet lead is described according to the weight per superficial foot, as 5-lb. lead, 6-lb. lead, &c.

Lead pipes, if of large diameter, are made of sheet lead, dressed round a wooden core, and soldered up.

Smaller pipes are cast in short lengths, of a thickness three or four four times that of the intended pipe, and either *drawn* or *rolled* out to the proper thickness.

Soft Solder is used for uniting the joints of lead-work. It is made of equal parts of lead and tin, and is purchased of the manufacturer by the plumber, at a price per lb., according to the state of the market.

263. *Laying of Sheet Lead.*—In order to secure lead-work from the injurious effects of contraction and expansion, when exposed to the heat of the sun, the plumber is careful not to confine the metal by soldered joints or otherwise. All sheet lead should be laid to a sufficient *current*, to keep it dry ; a fall of 1 in. in 10 ft. is sufficient for this purpose, if the boarding on which the lead is laid be perfectly even. Joints in the direction of the current are made by dressing the edges of the lead over a wooden *roll*, as shown in fig. 101.

Joints in the length of the current are made with *drips*, as shown on the left- hand-side of fig. 102.

Fig. 101.

Fig. 102.

Flashings are pieces of lead *turned down* over the edges of the other lead-work, which is *turned up* against a wall, as shown on the right-hand side of fig. 102, and serve to keep the wet from finding its way between the wall and the lead. The most secure way of fixing them is to build them into the joints of the brickwork, but the common method is to insert them about an inch into the mortar joint, and to secure them with wall hooks and cement. (*See* fig. 102.)

264. A very important part of the business of the plumber consists in fitting up cisterns, pumps, and water-closet apparatus, and in laying the different services and wastes connected with the same.

265 Plumber's work is paid for by the cwt., milled lead being rather more expensive than cast.

Lead pipes are charged per foot lineal, according to size.

Pumps and water-closet apparatus are charged at so much each, according to description; as also, basins, air traps, washers and plugs, spindle valves, stop-cocks, ball-cocks, &c.

Table of the Weight of Lead Pipes, per yard.

Bore.	lb.	oz.
$\frac{1}{2}$ inch	3	3
$\frac{3}{4}$ "	5	7
1 "	8	0
$1\frac{1}{4}$ "	11	0
$1\frac{1}{2}$ "	14	0
2 "	21	0

ZINC WORKER.

266. The use of sheet lead has been to a certain extent superseded by the use of sheet zinc, which, from its cheapness and lightness, is very extensively used for almost all

purposes to which sheet lead is applied. It is, however, a very inferior material, and not to be depended upon. The laying of it is generally executed by the plumber; but the working of zinc, and manufacturing of it into gutters, rain-water pipes, chimney cowls, and other articles, is practised as a distinct business.

GLAZIER.

267. The business of the glazier consists in cutting glass, and fixing it into lead-work, or sashes. The former is the oldest description of glazing, and is still used, not only for cottage windows, and inferior work, but for church windows, and glazing with stained glass, which is cut into pieces of the required size, and set in a leaden framework; this kind of glazing is called *fretwork.*

268. *Glazing in sashes* is of comparatively modern introduction. The sash-bars are formed with a *rebate* on the outside, for the reception of the glass, which is *cut into* the rebates, and firmly *bedded* and *backputtied* to keep it into its place. Large squares are also *sprigged*, or secured with small brads driven into the sash bars.

269. *Glazing in lead-work* is fixed in leaden rods, called *cames*, prepared for the use of the glazier by being passed through a glazier's vice, in which they receive the grooves for the insertion of the glass. The sides or cheeks of the grooves are sufficiently soft to allow of their being turned down to admit the glass, and again raised up and firmly pressed against it after its insertion.

For common lead-work, the bars are soldered together, so as to form squares or diamonds. In fretwork, the bars, instead of being used straight, are bent round to the shapes of the different pieces of glass forming the device—lead-work is strengthened by being attached to *saddle bars* of iron, by leaden bands soldered to the lead-work, and twisted round the iron.

Putty is made of pounded whiting, beaten up with linseed oil into a tough, tenacious cement.

270. The principal tool of the glazier is the *diamond*, which is used for cutting glass. This tool consists of an unpolished diamond fixed in lead, and fastened to a handle of hard wood.

The glazier uses a *hacking out knife*, for cutting out old putty from broken squares ; and the *stopping knife*, for laying and smoothing the putty when *stopping-in* glass into sashes.

For setting glass into lead-work the *setting knife* is used.

Besides the above, the glazier requires a square and straight edges, a rule and a pair of compasses, for dividing the tables of glass to the required sizes.

Also a hammer and brushes, for sprigging large squares, and cleaning off the work.

The *glazier's vice* has already been mentioned ; the *latterkin* is a pointed piece of hard wood, with which the grooves of the *cames* are cleared out and widened for receiving the glass.

271. Cleaning windows is an important branch of the glazier's business in most large towns ; the glazier taking upon himself the cost of repairing all glass broken in cleaning.

272. Glaziers' work is valued by the superficial foot, the price increasing with the size of the squares. Irregular panes are taken of the extreme dimensions each way.

Crown glass is *blown* in circular *tables* from 3 ft. 6 in. to 5 ft. diameter, and is sold in *crates*, the number of tables in a crate varying according to the quality of the glass.

A crate	contains	12	tables of	best quality.
,,	,,	15	,,	second do.
,,	,,	18	,,	third do.

Plate glass is *cast* on large plates on horizontal tables, and afterwards polished.

The manufacture of sheet or spread glass, which was formerly considered a very inferior article, has of late years been much improved ; much is now sold, after being polished, under the name of Patent Plate.

PAINTER, PAPERHANGER, AND DECORATOR.

273. The business of the house-painter consists in covering, with a preparation of white lead and oil, such portions of the joiner's, smith's, and plasterer's work as require to be protected from the action of the atmosphere. Decorative painting is a higher branch, requiring a knowledge of the harmony of colors, and more or less of artistic skill, according to the natnre of the work to be executed. The introduction of fresco painting into this country as a mode of internal decoration has led to the employment of some of the first artists of the day in the embellishment of the mansions of the wealthy ; and the example thus set will, no doubt, be extensively followed.

274. The principal materials used by the painter are *white lead*, which forms the basis of almost all the colors used in house-painting ; *linseed oil* and *spirits of turpentine*, used for mixing and diluting the colors ; and *dryers*, as litharge, sugar of lead, and white vitriol, which are mixed with the colors to facilitate their drying. *Putty*, made of whiting and linseed oil, is used for *stopping* or filling up nail holes, and other vacuities, in order to bring the work to a smooth face.

275. The painter's tools are few and simple ; they consist of the *grinding stone* and *muller*, for grinding colors ; *earthen pots*, to hold colors ; *cans*, for oil and turps ; a *pallet knife*, and *brushes* of various sizes and descriptions.

276. In painting wood-work, the first operation consists in *killing* the knots, from which the tnrpentine wonld otherwise exude and spoil the work. To effect this, the knots are

covered with fresh slaked lime, which dries up and burns out the turpentine. When this has been on twenty-four hours, it is scraped off, and the knots painted over with a mixture of red and white lead, mixed with glue size. After this they are gone over a second time with red and white lead, mixed with linseed oil. When dry, they must be rubbed perfectly smooth with pumice stone, and the work is ready to receive the priming coat. This is composed of red and white lead, well diluted with linseed oil. The nail holes and other imperfections are then stopped with putty, and the succeeding coats are laid on, the work being rubbed down between each coat, to bring it to an even surface. The first coat after the priming is mixed with linseed oil and a little turpentine. The second coat with equal quantities of linseed oil and turpentine. In laying on the second coat, where the work is not to be finished white, an approach must be made to the required color. The third coat is usually the last, and is made with a base of white lead, mixed with the requisite color, and diluted with one-third of linseed oil to two-thirds of turpentine.

Painting on stucco, and all other work in which the surface is required to be without gloss, has an additional coat mixed with turpentine only, which, from its drying of one uniform *flat* tint, is called a flatting coat.

If the knots show through the second coat, they must be carefully covered with silver leaf.

Work finished as above described would be technically specified as knotted, primed, painted three oils, and flatted.

Flatting is almost indispensable in all delicate interior work, but it is not suited to outside work, as it will not bear exposure to the weather.

277. Painting on stucco is primed with boiled linseed oil, and should then receive at least three coats of white lead and oil, and be finished with a flat tint. The great secret of success in painting stucco is that the surface should be

perfectly dry ; and, as this can hardly be the case in less than two years after the erection of a building, it will always be advisable to finish new work in distemper, which can be washed off whenever the walls are sufficiently dry to receive the permanent decorations

278. *Graining* is the imitation of the grain of various kinds of woods, by means of *graining tools*, and, when well executed, and properly varnished, has a handsome appearance, and lasts many years. The term graining is also applied to the imitation of marbles.

279. Clear coling (from *claire colle*, i. e. transparent size, Fr.), is a substitution of size for oil, in the preparation of the priming coat. It is much resorted to by painters on account of the ease with which a good face can be put on the work with fewer coats than when oil is used ; but it will not stand damp, which causes it to scale off, and it should never be used except in repainting old work, which is greasy or smoky, and cannot be made to look well by any other means.

280. *Distempering* is a kind of painting in which whiting is used as the basis of the colors, the liquid medium being size ; it is much used for ceilings and walls, and always will require two, and sometimes three coats, to give it a uniform appearance.

281. Painters' work is valued per superficial yard, according to the number of coats, and the description of work, as common colors, fancy colors, party colors, &c.

Where work is cut in on both edges, it is taken by the lineal foot. In measuring railings, the two sides are measured as flat work. Sash frames are valued per piece, and sashes at per dozen squares.

282. The manufacture of scagliola, or imitation marble, is a branch of the decorator's business, which is carried to very great perfection.

Scagliola is made of plaster of Paris and different earthy colors, which are mixed in a trough in a moist state, and blended together until the required effect is produced, when the composition is taken from the trough, laid on the plaster ground, and well worked into it with a wooden beater, and a small gauging trowel. When quite hard, it is smoothed, scraped, and polished, until it assumes the appearance of marble.

Scagliola is valued at per superficial foot, according to the description of marble imitated, and the execution of the work.

283. Gilding is executed with leaf gold, which is furnished by the gold-beater in books of 25 leaves, each leaf measuring $3\frac{1}{8}$ in. by 3 in. The parts to be gilded are first prepared with a coat of gold size, which is made of Oxford ochre and fat oil.

284. The operations of the paper-hanger are too simple to require description.

A piece of paper is 12 yards long, and is 20 ins. wide, when hung, and covers 6 ft. superficial; hence the number of superficial feet that have to be covered, divided by 60, will give the number of pieces required.

Paper-hangers' work is valued at per piece, according to the value of the paper.

The trades of the plumber, glazier, painter, paper-hanger, and decorator are often carried on by the same person.

DRAINAGE.

285. The principal classes of buildings as subjects for water supply and drainage, are—1. Dwellings; 2. Manufactories; and 3. Public buildings.

There is no certain date upon which to calculate the extent of the arrangement to be provided for the joint purposes of supplying water and discharging sewerage. In England the

calculations of water companies are usually based upon the rental paid for each house as an index to the consumption of water within it, and in this way they recognize an almost infinite number of classes.

286. It is estimated that 20 gallons of water is the average daily quantity for each inhabitant of a town, and that this quantity is sufficient to allow also for an ordinary proportion of manufacturing operations, for the supply of public buildings, and for the extinction of fires. It is estimated that a bulk of water measuring 6 feet in length by $1\frac{1}{2}$ feet in width and 1 ft. in depth, will suffice for the ablution of one person in the baths. This quantity will equal 9 cubic feet, or about 54 gallons.

287. Sewers and drains were formerly devised with the single object of making them *large enough*, by which it was supposed that their full efficiency was secured. But sluggishness of the action is now recognized as the certain consequence of excess equally as of deficiency of declination. A small stream of liquid matter extended over a wide surface, and reduced in depth in proportion to this width, suffers retardation from the want of declivity in the current. Hence a drain which is disproportionally large in comparison to the amount of drainage is concentrated within a more limited channel, a greater rapidity is produced, and every addition to the contents of the aids by the full force of its gravity in propelling the entire quantity forward to the point of discharge.

288. There are four conditions which are to be regarded as indispensable in the construction of all drains from all buildings whatsoever. These conditions are—First. That the entire length of drain is to be constructed and maintained with *sufficient declivity* towards the discharge into the sewer to enable the average proportion and quantity of liquid and solid matters committed to it to maintain a *constant* and *uninterrupted motion*, and that stagnation shall never occur.

Second. That the entire length of drain is to be constructed and maintained in a condition of *complete impermeability*, so that no portion of the matters put into it should escape from it. Third. That the head of the drain shall be so efficiently trapped that no gaseous or volatile properties or products can possibly arise from its contents. Fourth. That the lower extremity of the drain, or the point of its communication with the sewer, shall be so properly, completely, and durably formed, that no interruption to the flow of the drainage or escape shall take place, and that no facility shall be offered for the upward progress of the sewerage in case the sewer becomes surcharged, and thus tends to produce such an effect.

289. The common occupation of the basement stories of houses, as kitchens and water closets, has made it appear desireable to depress the drains and sewers, in order to receive the refuse matters below the level of these basements ; but as this object involves one or both of the evils we have pointed out, viz : deficient declivity and consequent stagnation in the drains, and a general system of sewers sunk so deeply in the ground that incomparable expense and difficulty are created in construction, access, and repairs, the purpose of basement draining should be abandoned, and practicable methods sought of delivering the entire drainage at the level of the surface ground.

290. Brick-work does not seem to be peculiarly fitted for drains. It requires smoothness and tightness. Stoneware, is more economical for this purpose than iron tubing, and is entirely free from the chance of corrosion and permeability. By glazing the interior surface, moreover, tubes of this ware are made peculiarly suitable for adoption in forming drains ; and carefully made socket joints laid in the direction of the current are cheaply executed, if moulded conically and luted with a little cement of the best quality. The size of the drain pipes has to be graduated according to the quantity to be passed through them.

291. The trapping of the head of the drain, so as to prevent the ascent of smell and impure gas from the drain into the building, is an indispensable requirement in draining apparatus. Simplicity of construction and permanence of action are, of course, required, with the least original outlay at which these qualities can be obtained.

292. The lower connection of the house drain with the public sewer is the last point of importance to which we allude. A perfect construction of this portion of the work has always been recognised as an essential feature of good drainage. The level of the bed of the drain must be kept as high as possible above that of the receiving sewer. If the sewer be also constructed of the glazed stone ware piping, lengths of it may be introduced at convenient intervals, having outlet sockets for receiving the ends of the house-drains, and being slightly tapered or conical in form will be readily jointed with a little of the best cement. If the sewer be constructed of brickwork, a good joint will be obtained by introducing a separate socket of stone-ware to receive the house-drain pipe, and formed with a flange at the other end to surround and cover the opening in the sewer, which can then be made good with a ring of cement carefully applied.

Means of access to house-drains are always desirable in arranging the details of the apparatus.

PAINTS.

293. Before you commence to paint a building, all holes, nail heads, and indentations should be filled in with putty. The *priming* should then be put on. The color will, of course, depend on the color of the paint to be put on. After the priming is perfectly dry, follow with another coat of priming, or a coat of paint.

Nut oil is better than linseed oil, to be mixed with paint, that requires exposure to the weather.

294. Painters require a *paint pot* in which to carry their paint, *brushes*, with which to put it on, *pencils*, or small, soft brushes for fine work, a *palette*, or small, thin, oval shaped board on which to spread paint when delicate work is being done, a *moll stick*, with which to steady the hand.

We cannot give recipes for making the various kinds of varnish and paints in this work.

SECTION V.

WORKING DRAWINGS, SPECIFICATIONS, ESTIMATES, AND CONTRACTS.

295. The erection of buildings of any considerable magnitude is usually carried on under the superintendence of a professional architect, whose duties consist in the preparation of the various working drawings and specifications that may be required for the guidance of the builder ; in the strict supervision of the work during its progress, to insure that his instructions are carried out in a satisfactory manner; and in the examination and revision of all the accounts connected with the works.

This brief enumeration of the duties of an architect will suffice to show how many qualifications are required in one who aims at being thoroughly competent in his profession. He must unite the taste of the artist with the science and practical knowledge of the builder, and must be at the same time conversant with mercantile affairs, and counting-house routine, in order that he may avoid involving his employer in the trouble and expense attendant on disputed accounts, which generally are the result of the want of a clear and explicit understanding, on the part of the builder, of the obligations and responsibilities of engagements based upon the incomplete drawings, or vaguely worded specifications of an incompetent architect.

296. The profession of the architect and the trade of the builder are sometimes carried on by the same person : but this union of the directive and executive functions is not to be recommended ; in the first place, because the duties of the workshop and the builder's yard leave little time for the study of the higher branches of architectural knowledge ;

and, in the second place, because the absence of professional control will always be a strong temptation to a contractor to prefer his own interests to those of his employer, however competent he may be to design the buildings with the execution of which he may be charged.

During the present century, the impulse given to our arts and manufactures, and the improvements effected in the internal communications of the country, have given rise to the execution of many extensive works requiring for their construction a large amount of mechanical and scientific knowledge; in consequence of which a new and most important profession has sprung up during the last thirty years, occupying a middle position between those of architecture and mechanical engineering, viz., that of the civil engineer. The practice of the architect and of the civil engineer so closely approximate in many respects, that it is difficult strictly to draw the line of demarcation between them; but it may be said in general terms that whilst the one is chiefly engaged in works of civil and decorative architecture, such as the erection of churches, public buildings, and dwelling-houses, the talent of the other is principally called forth in the art of construction on a large scale, as applied to retaining walls, bridges, tunnels, light-houses, &c., and works connected with the improvements of the navigation and internal communications of the country.

297. The business of the surveyor is often carried on as a distinct branch of architectural practice; and, as the title of surveyor is often appropriated to those who have no real claim to it, a few words on a surveyor's duties may not be here out of place.

Surveyors may be divided into three classes: land surveyors, engineering surveyors, and building surveyors.

The business of an engineering surveyor, as distinguished from that of a land surveyor, chiefly consists in the preparation of accurate plans, sections, and other data relative to

the intended sites of large works, which may be required by the architect or engineer preparatory to making out his working drawings, and in conducting leveling operations for drainage works, canals, railways, &c.

The building surveyor prepares, from the drawings and specifications of the architect or the engineer, bills of quantities of intended works, for the use of the builder on which to frame his estimates ; and, in the case of contracts, these bills of quantities form the basis of the engagements entered into by the builder and his employer, the surveyor being pecuniarly answerable for any omissions. The surveyor is also employed in the measurement of works already executed or in progress ; in the latter case, for the purpose of ascertaining the advances to be made at stated intervals, and is engaged generally in all business connected with builders' accounts.

298. The following is the general routine of proceedings in the case of large works. It will readily be understood that in small works subdivision of labor is not carried to such an extent, the architect superintending the works himself, without the aid of a clerk of works, and the builders taking out their own quantities.

I. The general design having been approved of, and the site fixed upon, an exact plan is made of the ground, the nature of the foundation examined, and all the levels taken that may be required for the preparation of the working drawings.

II. The architect makes out the working drawings, and draws up the specification of the work.

III. A meeting is held of builders proposing to tender for the execution of the proposed works, called either by public advertisement or private invitation, at which a surveyor is appointed in their behalf to take out the quantities. Sometimes two surveyors are appointed, one on the part of the builders, and one on the part of the architect, who take

out the quantities together, and check each other as they proceed.

IV. The surveyor having furnished each party proposing to tender with a copy of the bills of quantities, the builders prepare their estimates, and meet a second time to give in their tenders, after which the successful competitor and the employer sign a contract, drawn up by a solicitor, binding the one to the proper execution of the works, and the other to the payment of the amount of their cost at such times and in such sums as may be set forth in the specification.

V. The work is then set out,* and carried on under the constant direction of a foreman on the part of the builder, and on the part of the architect under the superintendence of an inspector or clerk of works, whose duty it is to be constantly on the spot to check the quality and quantity of material used, to see to the proper execution of the work, and to keep a record of every deviation from the drawings that may be rendered necessary by the wishes of the employer, or by local circumstances over which the architect has no control.

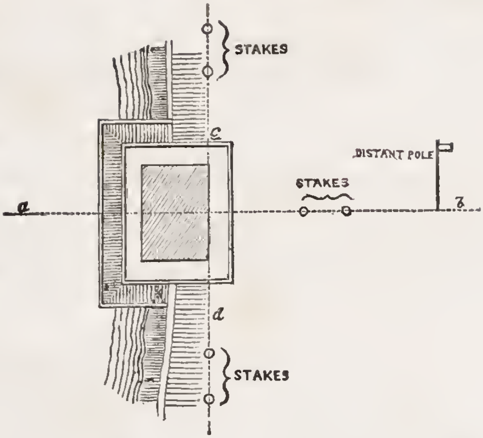
The work is measured up at regular intervals, and payments made on account to the builder, upon the architect's certificate of the amount of work done.

VI. The work being completed, the extras and omissions are set against each other, and the difference added to or deducted from the amount of the contract, and the whole business is concluded by the architect giving a final certificate for the payment of the balance due to the builder.

* *On Setting out Work.*—The determination of the exact position of an intended building being sometimes difficult to accomplish, a few remarks on the subject may be acceptable.

The setting out of the leading lines is simple enough on level ground, where nothing occurs to interrupt the view, or to prevent the direct measurement of the required distances ; but to perform this operation at the bottom of a foundation pit, blocked up with balks and shores and ankle-deep in slush, requires a degree of practice and patience not always to be met with. Let us take a simple

Fig. 103.



299. *Plan of Site.*—In preparing the plan of the site of the proposed works, the operations of the surveyor will

---

case, such as the putting in the abutment of a bridge or a viaduct, any error in the position of which would render the work useless (see fig. 103) The leading lines having been laid down on the drawings, the first thing to be done, before breaking ground, is to set out the centre line very carefully with a theodolite and ranging rods for a considerable distance on each side of the work, and to fix its positiou by erecting poles, planed true and placed perfectly upright, in some part of the line where there is no chance of their being disturbed.

Next, the exact position of the abutment on the centre line would be decided upon, and fixed by setting out another line at right angles to the first as $c\,d$ which wouldalso be extended beyond the works. and its position fixed by driving in stakes. the exact position of the line ou the head of the stake being marked by a saw cut

These guiding lines haviug now been permanently secured the plan of the abut·ment may be set out on the ground, the dams driven. and the earth got out to the required depth. By the time the excavation is ready for commencing the work, it generally presents a forest of stays, struts, and shores that would defy any attempt at setting out the work on its own level ; it must therefore be set out at the top of the dam, aud the points transferred or *dropped*, as follows : —

First, the position of the centre line is ascertained by reference to the poles, and nails being driven into the timbers at the sides of the dam, a fine line is strained across ; the position of the line $c\,d$ is found, and a second line strained across in the same way. In a similar manner other lines are strained from side to side at the required distances, the length being measured from the line $c\ d$, and the widths from $a\,b$, until the outline of the foundation course is found ; the angle points are then transferred to the bottom of the excavation by means of plumb-lines, and the work is commenced. its accuracy being easily tested by measurements from the lines $a\ b$ and $c\ d$, until it is so far advanced as to render this unnecessary.

generally have to be extended beyond the spot of ground on which the building is to stand. The frontages of the adjacent buildings, and the position of all existing or contemplated sewers, drains and water-courses, should be correctly ascertained and laid down. Sketches drawn to scale of the architectural sketches of the adjacent buildings, if in town, and accurate outline sketches of the *incidents* of the locality of the intended operations, if in the country, should accompany the plan, that the architect may try the effect of his design before its actual execution renders it impossible to remedy its faults.

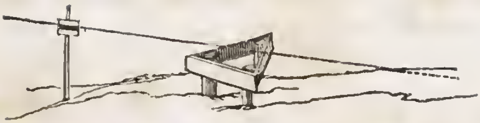
By the careful study of all these data the architect may hope to succeed in making his works harmonize with the objects that surround them ; without them, failure on this head is almost a certainty.

300. *Levels.*—Where the irregularities of the ground are considerable, it is necessary to ascertain the variations of the surface before the depth of the foundations and the position of the floors can be decided upon.

It also frequently happens that the levels of the floors and other leading lines, in a new building, are regulated by the capabilities of sewerage or drainage, or by the heights of other buildings with which the new work will ultimately be connected, as in the case of new streets. It therefore becomes of importance to have simple and accurate means of ascertaining and recording the relative heights of different points. For this purpose both the spirit level and the mason's level are used.

301. Where the ground to be leveled over is limited in extent, and the variations of level do not exceed 12 feet, the heights of any points may be found with the mason's level in the following manner. (*See* fig. 104.)

Fig. 104.



In a convenient place, near the highest part of the ground, drive three stout stakes at equal distances from each other, and nail to them three pieces of stout plank, placed as shown in the cut, their upper edges being adjusted to the same horizontal plane by means of the mason's level. The level being then placed on this frame, an assistant proceeds to the first point of which the height is required, holding up a rod with a sliding vane, which he raises or lowers in obedience to the directions of the surveyor, until it coincides with a pair of sights fixed at the bottom of the level; the height of the vane will then be the difference of level between the top of the leveling frame, and the place where the staff was held up.

302. The above and similar methods will suffice for taking levels in a rough way for the ordinary purposes of the builder; but where great accuracy is requisite, or where the levels have to be extended over a considerable distance, as is often the case in drainage works, the use of a more perfect contrivance is necessary, and the spirit level is the instrument principally used for this purpose.

The spirit level consists of a telescope mounted on a portable stand, and furnished with screw adjustments, by means of which it can be made to revolve in a horizontal plane, any deviation from which is indicated by the motion of an air-bubble in a glass tube fixed parallel to the telescope.

The eye-piece of the telescope is furnished with cross-wires, as they are technically termed, made of spiders' thread, of which the use will be presently explained.

303. The leveling staff, now in common use, is divided

into feet, tenths, and hundredths, in a conspicuous manner, so that, with the help of the glass, every division can be distinctly seen at the distance of one hundred yards or more. The mode of conducting the operation of leveling is as follows :—

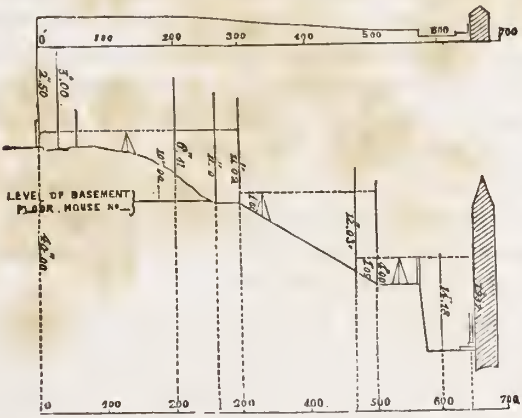
The surveyor having set up and adjusted his instrument, the staff-holder proceeds to the point at which the levels are to commence, and holds up his staff perfectly upright and turned towards the surveyor, who notes the division of the staff which coincides with the horizontal wire in the telescope, and enters the same in his level-book ; the staff-holder then proceeds to the next point, and the reading of the staff is noted as before ; and this is repeated until the distance or the difference of level makes it necessary for the surveyor to take up a fresh position. While this is being done, the staff-holder remains stationary, until, the level being adjusted again, he carefully turns the face of the staff so as to be visible from the instrument in its new position, and a second reading of the staff is noted, after which he proceeds forward as before for a fresh set of observations.

304. In every set of observations the first is called a Backsight, and the last a Foresight. The remaining observations are called intermediates, and are entered accordingly. It will be seen that an error in an intermediate reading is confined to the point where it occurs ; but a mistake in a back or foresight is carried throughout the whole work, and therefore every care should be taken to insure accuracy in observing these sights.

305. The surveyor should commence and close his work by setting the staff on some well-defined mark, which can readily be referred to at any subsequent period, such as a door-step, plinth of a column, &c. These marks are called bench marks, written B M, and are essential for either checking the work or carrying it on at a subsequent period.

306. The reduction of the levels to a tabular form for use is a simple arithmetical operation, which will be readily understood by examination of the annexed example of a level book, and of the accompanying section*, fig. 105. The difference between the successive readings in any set of

Fig. 105.



observations is the difference of level between the points where the staff was successively held up, and by simple addition or subtraction, according as the ground rises or falls, we might obtain the total rise or fall of the ground above or below the starting point ; but as this would require two columns, one for the total rise, and one for the total fall, it is simpler to assume the starting point to be some given height above an imaginary horizontal *datum line,* drawn below the lowest point of the ground, to which level all the heights are referred in the column headed total height above datum line

307. The accuracy of the arithmetical computations is

* In plotting sections of ground, it is usual to make the vertical scale much greater than the horizontal, which enables small variations of level to be easily measured on the drawing without its being extended to an inconvenient length. This is shown in the lower half of fig. 105. The upper part of the figure shows the section plotted to the same horizontal and vertical scale.

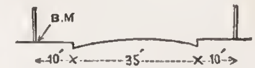
proved by adding up the foresights and backsights, and, deducting the sum of the former from that of the latter (the height of the first B M having been previously entered at the top of the page as a backsight), the remainder will be the height of the last B M, and should agree with the last figures in the column of total heights.

308. In leveling the site of a proposed building, if no suitable object presents itself for a permanent B M for future reference, a large stake, hooped with iron, should be driven into the ground in some convenient place where it will not be disturbed. The height of this stake being then carefully noted and marked upon the elevations and sections of the building, it will serve as a constant check on the depths of the excavations, and the heights of the different parts of the work, until the walls reach the level of the principal floor, when it will no longer be required.

309. We must not leave the subject of levels without mentioning a very useful instrument, called the water level, which consists of a long flexible pipe, filled with water, and terminating at each end in an open glass tube. When it is required to find the relative heights of any two points, as, for instance, the relative levels of the floors of two adjoining houses, the two ends of the tube are taken to the respective points, the tube being passed down the staircases, over the roofs, or along any other accessible route, no matter how circuitous, and the required levels are found by measuring up from the floors to the surface of the water, which will of course stand at the same level at each end of the tube

WORKING DRAWINGS.

310. The architect, being furnished with the plan and levels of the site of his operations, and having caused a careful examination to be made of the probable nature of the foundation by digging pits or taking borings, proceeds to make out his working drawings.

Readings of the Staff.			Difference of Readings.		Reduced levels.		Remarks.
Back sight.	Intermediate.	Fore sight.	Rise.	Fall.	Total height above datum line.	Distance in feet.	Levels of Building Ground at —— (Date).
40·00 Height of 1st BM above datum.							
2·50	...	...			40·00	—	B M on doorstep of garden, No. — Park Road.
			...	0·50			
	3·00	...			39·50	30	On centre of Park Road. 
			...	7·00			
	10·00	...			32·50	...	Level of basement floor at No. — * * * Terrace.
				1·00			
	11·00		...		31·50	260	
1·60		11·02		0·02			Terrace walk.
			...		31·48	300	
2·05		12·03		10·43			
					21·05	475	
	4·00	...	...	1·95			
					19·10	500	
	14·18	...	...	10·18			
					8·92	600	Centre of Lower Road.
		13·32	0·86	...			
46·15					9·78	...	B M top of doorstep, No. — Lower Road.
36·37		36·37					
9·78 Reduced level of last B M.							

It is not sufficient for the execution of the working drawings that the draughtsman should be acquainted with the ordinary principles of geometric projection. He must also be thoroughly conversant with perspective, and with the principles of chiascuro, or light and shade, or he will work at random, as the geometrical projections which are required for the use of the workman give a very false idea of the effect the work will have in execution.

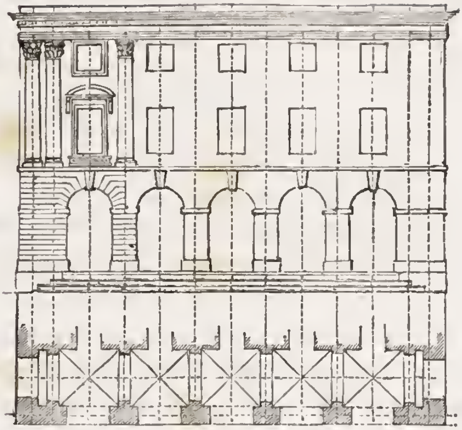
311. Working drawings may be divided under three heads, viz. :—Block plans, General drawings, and Detail drawings :

I. *Block plans.*—These show the outline only of the intended building, and its position with regard to surrounding objects. They are drawn to a small scale, embracing the whole area of the site, and on them are marked the existing boundary walls, sewers, gas and water mains, and all the new walls, drains, and water-pipes, and their proposed connection with the existing ones, so that the builder may see at a glance the extent of his operations.

A well-digested block plan, with its accompanying levels, showing the heights of the principal points, the fall of the drains, &c., is one of the first requisites in a complete set of working drawings.

II. *General Drawings.*—These show the whole extent of the building, and the arrangement and connection of the different parts more or less in detail, according to its size and extent. These drawings consist of *Plans* of the foundations, and of the different stories of the building, and of the roofs ; *Elevations* of the different fronts ; and *Sections* showing the heights of the stories, and such constructive details as the scale will admit of. These drawings are carefully figured, the dimensions of each part being calculated, and its position fixed by reference to some well-defined line in the plans or elevations, the position of which admits of easy

Fig. 106



verification in all stages of the work. This is best done by ruling faint lines on the drawings, through the principal divisions of the design, as shown in fig. 106, where the plan and elevation are divided into compartments, by lines passing through the centres of the columns, from which all the dimensions are dated each way. These centre lines are, in the execution of the work, kept constantly marked on the walls as they are carried up, so that they are at all times available for reference.

By this means, the centre lines having been once carefully marked on the building, any slight error or variation from the drawings is confined to the spot where it occurs, instead of being carried forward, as is sometimes the case, to appear only when correction is as desirable as it is impossible.

The use of these centre lines also saves much of the laboi of the draughtsman, as they form a skeleton, of which only so much need be filled up as may be required to show the design of the work.

III. *Detailed Drawings.*—These are on a large scale, showing those details of construction which could not be

explained in the general drawings, such as the framing of floors, partitions, and roofs, for the use of the carpenter; the patterns of cast-iron girders and story posts for the iron-founder; decorative details of columns, entablatures, and cornices, for the carver; the requisite details being made out separately, as far as possible, for each trade; which arrangement saves much time that would otherwise be wasted in referring from one drawing to another, and, which is still more important, insures greater accuracy, from the workman understanding better the nature of his work.

In making the detailed drawings every particular should be enumerated that may be required for a perfect understanding of the nature and extent of the work. Thus, in preparing the drawings for the iron-founder, every separate pattern should be drawn out, and the number stated that will be required of each.

This principle should be attended to throughout the whole of the detailed drawings, as, in the absence of such data, it is very difficult to prepare correct estimates for the execution of the work, without devoting more time to the study of the drawings than can generally be obtained for that purpose.

SPECIFICATION.

312. The drawings being completed, the architect next draws up the specification of the intended works. This is divided under two principal heads—1st, the conditions of the contract; and, 2d, the description of the work.

The title briefly states the nature and extent of the works to be performed, and enumerates the drawings which are to accompany and to form part of the written specification.

313. *Conditions of Contract.*—Besides the special clauses and provisions which are required by the particular circumstances of each case, the following clauses are inserted in all specifications:

1. The works are to be executed to the full intent and meaning of the drawings and specification, and to the satisfaction of the architect.

2. The contractor to take the entire charge of the works during their progress, and to be responsible for all losses and accidents until their completion.

3. The architect is to have power to reject all improper materials or defective workmanship, and to have full control over the execution of the works, and free access at all times to the workshops of the contractor where any work is being prepared.

4. Alterations in the design are not to vitiate the contract, but all extra or omitted works are to be measured and valued according to a schedule of prices previously agreed upon.

5. The amount of the contract to be paid by instalments as the works proceed, at the rate of — per cent. on the amount of work done, and the balance within ——— from the date of the architect's final certificate.

Lastly. The works are to be completed within a stated time, under penalties which are enumerated.

314. *The description of the works* details minutely the quality of the materials, and describes the manner in which every portion of the work is to be executed, the fulness of the description depending on the amount of detailed information conveyed by the working drawings, care being taken that the drawings and specification should, together, contain every particular that is necessary to be known in order to make a fair estimate of the value of the work.

315. The chief merit of a specification consists in the use of clear and explicit language, and in the systematic arrangement of its contents, so that the description of each portion of the work shall be found in its proper place; to facilitate

reference, every clause should be numbered and have a marginal reference attached, and a copious index should accompany the whole.

BILLS OF QUANTITIES.

316. The surveyor, being furnished by the architect with the drawings and specification, proceeds to take out the quantities for the use of the parties who propose to tender for the execution of the work. This is done in the same way that work is measured when executed, except that the measurements are made on the drawings with a scale instead of on the real building with measuring rods.

317. In taking out quantities there are three distinct operations: 1st, taking the dimensions of the several parts of the work, and entering them in the dimension book; 2dly, working out the quantities, and posting them into the columns of the abstracts, which is called *abstracting;* 3dly, casting up the columns of the abstracts, and bringing the quantities into bill.

318. The dimension book is ruled, and the dimensions entered as in the following examples:

No.	Dimension.	Quantity.	Description.
	ft. in.	ft. in.	
16	14 0		
	0 10	38 10	Memel fir framed joists to front room ground floor.
	0 2½		

In this example the work measured consists of sixteen joists; each 14 ft. long and 10 in. deep and 2½ in. thick; and the total quantity of timber they contain amounts to 38 ft. 10 in. cube.

Dimension.	No. of bricks in thickness.	Quantity.	Description
ft. in. 20 6 11 6	} 2½	ft in. 235 9	} Stock brickwork in mortar to front wall, from footings to 1st set-off.

319. In preparing the abstract for each trade, the surveyor looks over his dimensions to see what articles he will have, and rules his paper into columns accordingly, writing the proper heads over each.

The principal point to be attended to in abstracting quantities is to preserve a regular rotation in arranging the different descriptions of work, so that every article may at once be found on referring to its proper place in the abstract.

No fixed rules can be given on this head, as the form of abstract is different for every trade, and must be varied according to circumstances ; but, as a general principle, articles of least value should be placed first. Solid measure should take precedence of superficial, and superficial of lineal, and miscellaneous articles should come last of all ; or, in technical terms, the rotation should be, 1st, cubes ; 2nd, supers.; 3rd, runs ; and, lastly, miscellaneous.

320. In bringing the quantities into bill, the same rotation is to be observed as in abstracting them, care being taken that every article is inserted in its proper place, so that it may readily be found in the bill.

The limits of this volume prevent our going into much detail on the subject of builders' accounts, and we must therefore confine ourselves to laying before the reader a skeleton estimate, which will give him a tolerable idea of the manner in which the several kinds of artificers' work are abstracted and brought into bill.

321. Estimate for the Erection of ——— at ———, for ———, according to Specification and Drawings numbered 1 to —, prepared by ———, Architect. (Date.)

Foundations.

					Dolls.	Cts.
yds.	ft.					
—	—	cube	Excavation to foundations, (including cofferdams, pumping, &c.) . . .	at —		
—	—	"	Concrete			
ft.	in.					
—	—	"	Timber in piles driven — ft. through, (describe the material,) including ringing, shoeing and driving, but not ironwork . . .			
—	—	"	Do. in 6-in. planking, spiked to pile-heads . . .			
cwt.	qrs.	lbs.				
—	—	—	Wrought iron in shoes to piles			
			Total of foundations to be carried to summary .			

Bricklayer.

					Dolls.	Cts.
rods.	ft.					
—	—	supl	Reduced brickwork in mortar	at —		
—	—	"	Reduced brickwork in cement			
sqrs.	ft					
—	—	"	Tiling (describing the kind, whether plain or pantiling, if single or double laths, &c., &c.)			
yds.	ft.					
—	—	"	Bricknogging to partitions .			
—	—	"	Paving, (of various descriptions)			
			And all other articles valued per yard superficial.			
ft.	in.					
—	—	"	Gauge arches			
—	—	"	Facings (with superior description of bricks, specifying the quality) . .			
—	—	"	Cutting to arches or splays .			
			And all other work valued by the foot superficial.			
—	—	run	Barrel or other drains (specifying size, &c.) . . .			
			Carried forward	$		

BRICKLAYER, *continued.*

						Dolls.	Cts.
			Brought forward . .				
—	—	run	Tile creasing . . .	at —			
			And all other articles valued by running measure.				
		Nos.	Chimney pots, each ; bedding and pointing sash and door frames, each ; and all miscellaneous articles . .				
			Total of bricklayers' work to be carried to summary				
			MASON.				
yds.	ft.						
—	—	cube	Rubble walling . . .	at —			
—	—	,,	Hammer-dressed walling in random courses . .				
ft.	in.						
—	—	,,	Stone (describing the kinds).				
—	—	supl.	Labor on above (as plain work, sunk, moulded or circular work) . . .				
—	—	,,	Hearths, pavings, landings, &c., beginning with the thinnest				
—	—	,,	Marble slabs, beginning with the thinnest and inferior qualities				
—	—	run	Window sills, curbs, steps, copings, &c.				
—	—	,,	Joggle joints, chases, &c. .				
		Nos.	Mortices and rail holes, &c.—dowels, cramps, and other articles numbered .				
			Total of masons' work to be carried to summary .				
			CARPENTER AND JOINER.				
sqrs.	ft.						
—	—	supl	Labor and nails to roofs, floors, or quarter partitions	at —			
—	—	,,	Battenings and boardings according to description .				

Carried forward . . $

CARPENTER & JOINER, *continued.*

ft.	in.				Dolls.	Cts
—	—	supl.	Floors, according to description, beginning with the inferior and ending with the best descriptions .	at —		
			And so on for all work valued by the square.			
—	—	cube	Memel fir, according to description, as fir bond, fir framed, wrought and framed, wrought, framed, and rebated, &c. . . .			
—	—	„	Do. proper door and window cases			
			Then oak, and superior descriptions of timber, in the same way.			
			Then the superficial work, as—			
—	—	supl.	½-in. deal rough linings, and so on with the different thicknesses of deals according to the labor on them; arranging them according to their thickness, and the amount of labor on them, beginning with the thinnest			
			Then oak plank or mahogany in the same way.			
			Then take the framed work, as—			
—	—	„	1¼-in. deal square-framed inclosure to closets, and so on with the rest of the framed work, as doors, shutters, sashes, frames, &c., according to description . .			
			Then the work valued by running measure, as—			
—	—	run	2¼-in. Spanish mahogany moulded, grooved, and beaded handrail . . .			
			Then the numbers, as—			
		Nos.	Mitred and turned caps, fixing iron balusters, &c.			

Carried forward . . $

CARPENTER & JOINER, *continued.*

					Dolls.	Cts.
			Brought forward . .			
			Lastly — The Ironmongery, every article of which should be carefully described.			
			Total of carpenter and joiners' work to be carried to summary . .			
			SLATER.			
sqrs.	ft.					
—	—	supl.	Countess, or any other kind of slating, according to description	at —		
ft.	in.		Then slate slab, as—			
—	—	"	Inch shelves, rubbed one side, beginning with the slabs of least thickness, and arranging them according to the labor bestowed on them .			
			Then the work valued by running measure, as—			
—	—	run.	Patent saddle-cut slate ridge			
			Lastly—the numbers, as—			
		Nos.	Holes, cut, &c. . . .			
			Total of slaters' work to be carried to summary .			
			PLASTERER.			
			First the superficial quantity of plastering, as—			
yds.	ft.					
—	—	supl.	Render float and set to walls, beginning with the commonest, and proceeding through the different descriptions of two and three coat work, up to the stuccoes and superior work .	at —		
			Then the whitewashing, distempering, &c. . . .			
			Next the run of cornices, architraves, reveals, &c., as—			
			Carried forward .	$		

PLASTERER, *continued.*

			Dolls.	Cts.
ft. in	Brought forward . .			
— — run.	Plain cornice to drawing-room, 14 in. girt . .			
	And lastly the numbers, as—			
Nos	4 mitres, 1 centre flower, 30 in. diameter, &c., &c. .			
	Total of plasterers' work to be carried to summary .			
	SMITH AND IRON-FOUNDER.			
	Begin with the cast-iron, as—			
tns. ct. qrs. lb. — — — —	Cast-iron in No. 4 girders, including patterns, painting, and fixing . . .	at —		
	N. B.—State the No. of patterns.			
	Then the smaller castings, as—			
	Railings, balconies, columns, &c.			
	Then the wrought iron, as—			
— — — —	Wrought iron in chimney bars, straps, screw bolts, railings, &c.			
	Then the articles sold by running measure, as— .			
yds. ft. — — run.	Cast-iron gutters, water-pipes, &c.			
	Lastly, the numbers, as—			
Nos.	Stoves, coal-plates, stable-fittings, &c.			
	Total smith and iron-founders' work to be carried to summary . . .			
	BELL-HANGER.			
	Number the bells, and describe the mode of hanging, as—			
	Carried forward . .	$		

BELL-HANGER, *continued.*

					Dolls.	Cts.
			Brought forward . .			
		Nos.	— bells hung with copper wires in concealed tin tubes, with bells, cranks, and wires complete . .			
			And then enumerate the ornamental furniture to the different pulls . . .			
			Total of bell-hangers' work to be carried to summary			
			PLUMBER.			
cwt.	qrs	lbs.				
—	—	—	Cast lead laid in gutters, hips, ridges, flats, cisterns, &c.; including all solder, wall hooks, nails, &c. .	at —		
—	—	—	Milled do. do. . .			
			Then socket, rain-water, funnel pipes, and other work valued by the lineal foot, as—			
ft.	in.					
—	—	run.	Inch drawn pipes . .			
			Lastly the numbers, as—			
		Nos.	Joints, plugs, and washers, air traps, brass grates, cocks, copper balls, pumps, water closets, apparatus, &c.			
			Total of plumbers' work to be carried to summary .			
			PAINTER.			
yds.	ft.					
—	—	supl.	Of painting, according to description, specifying the number of oils, and whether common or extra colors, beginning with the work in fewest coats, and finishing with the most expensive descriptions . .			
			Carried forward .	$		

PAINTER, *continued.*

					Dolls.	Cts.
			Brought forward . .			
			Then the running work, as—			
ft.	in.					
—	—	run.	Skirtings, plinths, window sills, &c.			
			Lastly the numbers, as—			
		Nos.	Frames, squares, chimney pieces, &c. . . .			
			Total of painters' work to be carried to summary .			

GLAZIER.

					Dolls.	Cts.
ft.	in.					
—	—	supl.	Glazing, according to description, specifying size of squares, and quality of glass	at —		
			Then, the stained and other ornamental glass; and, lastly, the plate glass.			
			Total of glazier's work to be carried to summary .			

PAPER-HANGER & DECORATOR.

					Dolls.	Cts.
yds.	ft.					
—	—	supl	Distempering, according to description . . .	at —		
ft.	in.					
—	—	"	Scagliola slabs do. . .			
yds.	ft.					
—	—	run	Gold mouldings . . .			
		Nos.	Pieces of paper hung, according to description, including preparing walls— Hanging, lining, paper, and pumicing do. . .			
		"	Dozen of borders . . .			
			Total of paper-hanger and decorator's works to be carried to summary .			

SUNDRIES.	DOLLS.	CTS
Temporary fencings—watching and lighting works		
Office for clerk of works		
District surveyor's fee		
Fire insurance		
Surveyor's charge for bills of quantities .		
Total sundries to be carried to summary		

SUMMARY OF BILLS.	DOLLS.	CTS
Foundations		
Bricklayer		
Mason		
Carpenter and joiner		
Slater		
Plasterer		
Smith and iron-founder		
Bell-hanger		
Plumber, painter, and glazier . . .		
Paper-hanger and decorator . . .		
Sundries		
Total amount of estimate . . .		

322. The surveyor furnishes the builder, whose tender is accepted, with copies of the drawings from which the quantities have been taken off

By reference to these, the builder can at all times satisfy himself that the detailed drawings, furnished for the execution of the work, contain nothing beyond what he has contracted for.

Copies of the drawings and specification are attached to the contract deed, and are signed by the builder and other parties respectively concerned.

323. It scarcely ever happens that a large undertaking can be carried into execution without considerable departure from the contract designs, especially in the matter of foundations and underground work ; the exact nature and extent of which must often be uncertain until the works are commenced.

To provide for these contingencies without setting aside the contract, the builder's estimate is accompanied by a schedule of prices at which he undertakes to execute any additional work that may be required, or to value any work that may be omitted. This schedule should be carefully drawn out, so that there shall be no dispute as to its meaning; thus, under the head of brickwork, it should be clearly understood whether centering is included in the price named, or whether it is to form an additional charge; with iron-founders' work, whether the price includes patterns; and so on with every description of work.

324. Architects are remunerated by a commission of 5 per cent. on the amount expended under their direction, besides traveling expenses, salary of the clerk of the works, and occasionally other charges, according to circumstances.

APPENDIX.

WOODS OF NORTH AMERICA.

1. *Abies alba*, or white spruee; weighs 23 lbs. 13 oz. per eubic foot; speeifie gravity, .381.

2. *Abies canadensis*, or hemlock-spruee; common in Upper Canada; weighs 23 lbs. 0 oz. per eubic foot, and has a speeific gravity of .368.

3. *Acer eriocarpum*, or soft maple; eommon in Upper Canada; weighs 36 lbs. 14 oz., and has a speeific gravity of .590.

All the above are used in earpentry.

4. *Acer negrundo*, or box-elder, ash-leaved maple; eommon in the United States; weighs 24 lbs. per cubic foot, and has a specific gravity of .384.

5. *Acer rubrum*, or red maple; eommon in the United States; weighs 38 lbs. 5 oz. per eubie foot—has a speeifie gravity of .613.

6. *Ascer saccharinum*, or sugar mable; common in the United States; weighs 38 lbs. 6 oz. per cubie foot, and has a speeifie gravity of .614.

7. *Ascer saccharinum*, or bird's-eye maple; common in Upper Canada; used in ornamental work by earpenters and joiners; weighs 40 lbs. 15 oz. per eubie foot, and has a specific gravity of .655.

8. Curly maple; eommon in Upper Canada; used in common earpentry work; has a speeifie gravity of .586, and weighs 36 lbs. 10 oz. per eubie foot.

9. Hard maple; also common in Upper Canada; weighs 39 lbs. per eubic foot, and has a speeifie gravity of .634.

10. *Betula nigra*, or black bireh; eommon in Upper Canada; is mueh used for ship-building in Canada and Nova Scotia, but is not a durable wood; it weighs 35 lbs. 7 oz. per eubic foot, and has a speeifie gravity of .567.

11. Birch; an inferior wood—common in Canada and the Northern States; weighs 30 lbs. 11 oz. per cubic foot, and has a specific gravity of .491.

12. Butter wood; used in ship-building; has a specific gravity of .460, and weighs 28 lbs. 12 oz. per cubic foot.

13. *Carya porcina*, or pignut hickory; common in the United States; is the strongest and best kind of hickory; it weighs 49 lbs. 8 oz. per cubic foot, and has a specific gravity of .690.

14. *Carya sulcata*, or shell-bark hickory; common in the United States; weighs 43 lbs. 2 oz. per cubic foot, and has a specific gravity of .690.

15. Hickory; common in the United States; weighs 47 lbs. 8 oz. per cubic foot, and has a specific gravity of .760.

16. *Castanea vesca*, or chesnut; common in the United States; has a specific gravity of .404, and weighs 25 lbs. 4 oz. per cubic foot.

17. *Celtis crassifolia*, or hack berry; is a tough and elastic wood, weighing 38 lbs. 6 oz. per cubic foot, and has a specific gravity of .614.

18. *Cerasus virginiana*, or wild cherry; common in the United States; the bark is used medicinally; has a specific gravity of .515, and weighs 32 lbs. 3 oz. per cubic foot.

19. *Cerasus canadensis*, or red bud, Judas tree; a close-grained and compact wood, having a specific gravity of .535, and weighs 33 lbs. 7 oz. per cubic foot.

20. *Cornus florida*, or dog-wood; a hard, close-grained, and strong wood, weighing 47 lbs. 4 oz. per cubic foot, and having a specific gravity of .756.

21. *Cupressus disticha*, or cypress; common in the United States; grows to an immense size; is much used for shingles; weighs 22 lbs. 13 oz. per cubic foot, and has a specific gravity of .365.

22. *Diospyrus virginiana*, or persimon; a hard, close-grained wood; weighs 44 lbs. 6 oz. per cubic foot, and has a specific gravity of .710.

23. *Fagus americana*, or white beach; common in the United

States; is used in dry carpentry; weighs 42 lbs. 11 oz. per cubic foot, and has a specific gravity of .674.

24. *Fagus ferruginea*, or beech; common in Upper Canada, used in dry carpentry; the wood has a more rufous tint of color than common beech; it weighs 36 lbs. 9 oz. per cubic foot, and has a specific gravity of .585.

25. *Fraxinus americanus*, or American ash; weighs 35 lbs. 10 oz. per cubic foot, and has a specific gravity of .570;—is tough, and elastic.

26. White ash; weighs 30 lbs. 14 oz. per cubic foot, and has a specific gravity of .494.

27. *Gleditschia triacanthus*, or honey locust: is a very hard wood and splits easily, having a specific gravity of .646, and weighing 40 lbs. 6 oz. per cubic foot.

28. *Gymnocladus canadensis*, or coffee tree; is a hard, compact, strong, and tough wood, having a specific gravity of .647, and weighing 40 lbs. 7 oz. per cubic foot.

29. *Juglans alba*, or hickory; has a specific gravity of .770, and weighs 48 lbs. 2 oz. per cubic foot.

30. *Juglans cinerea*, or butternut; has a specific gravity of from .376 to .487, and weighs from 22 to 30 lbs. per cubic foot.

31. White walnut.

32. *Juglans nigra*, or black walnut; weighs 28 lbs. 15 oz. per cubic foot, and has a specific gravity, of .483 It is a strong and tough wood, not liable to split, and is much used in carpentry work.

33. *Juniperus bermudiana*, or red or pencil cedar; is used in ship-building and for making pencils.

34. The Virginia cedar is used for the same purpose, but is not considered as good as that from Bermuda.

35. *Larix americana*, or hackmatack; much used and esteemed in British North America for ship-building; has a specific gravity of about .600, and weighs about 36 lbs. per cubic foot.

36. The tamarack is a wood much used for ship-building in

British North America; it has a specific gravity of .383, and weigh 23 lbs. 15 oz. per cubic foot.

37. *Cedar.*—The samples at the World's Fair had a specific gravity of from .294 to .314, and weighed from 18 lbs. 6 oz. to 19 lbs. 10 oz. per cubic foot.

38. *Liriodenron tulipifera*, or yellow poplar; is common in the United States; has a specific gravity .287, and weighs 24 lbs. 8 oz. per cubic foot.

39. *Morus rubra*, or red mulberry; weighs 35 lbs. 1 oz. per cubic foot, and has a specific gravity of .561.

40. *Nyssa Multiflora*, or black gum, or sour gum; weighs 40 lbs. 6 oz. per cubic foot, and has a specific gravity of .646.

41. *Ostrya virginica*, or iron wood; weighs 48 lbs. 11 oz. per cubic foot, and has a specific gravity of .779.

42. *Picea balsamea*, or balsam; is used in carpentry; has a specific gravity of .304, and weighs 19 lbs. per cubic foot.

43. *Pinus mitis*, or yellow pine; has a specific gravity of .376, and weighs 23 lbs. 8 oz. per cubic foot.

44. *Pinus resinosa*, or American red pine; is used in carpentry; weighs 26 lbs. 11 oz. per cubic foot, and has a specific gravity of .427.

45. Red Pine; is a strong wood used in carpentry; has a specific gravity of .455, and weighs 28 lbs. 7 oz. per cubic foot.

46. *Pinus rigida*, or pitch pine; is a strong wood, weighing 32 lbs. per cubic foot, and having a specific gravity of .512.

47. *Platanus occidentalis*, or button-wood, or sycamore; is much used for making beadsteads; has a specific gravity of .424, and weighs 26 lbs. 8 oz. per cubic foot.

48. *Populus*, or poplar; is a light, inferior wood.

49. Cherry wood; weighs 29 lbs. 15 oz. per cubic foot, and has a specific gravity of .479.

50. Quebec oak; is much used for ship building, but is not durable.

51. *Quercus alba,* or white oak; weighs 40 lbs. per cubic foot, and has a specific gravity of .64.

52 *Quercus rubra,* or red oak; weighs 32 lbs. 2 oz. per cubic foot, and has a specific gravity of .514.

53. *Quercus tinctoria,* or black oak; weighs 34 lbs. 13 oz., and has a specific gravity of .558.

54. *Quercus virens,* or live oak; is the heaviest and hardest of the oaks; has a specific gravity of .100, and weighs 56 lbs. 4 oz. per cubic foot.

55. *Robinia pseud acacia,* or locust, or treenail; so called because used principally for treenails.

56. *Sassafras officinale,* or sassafras tree.

57. *Tilia americana,* or bass-wood; is even in grain, weighs 25 lbs. per cubic foot, and has a specific gravity of .400.

58. *Ulmus americana,* or elm; weighs 36 lbs. 11 oz. per cubic foot, and has a specific gravity of .587.

59. Red elm—used by wheelwrights.

60. White elm.

61. Rock elm.

62. Swamp elm. These elms are all quite similar.

63. Quebec rock elm, or wych hazel; used in ship-building in Canada; has a specific gravity of .546, and weighs 34 lbs. 2 oz. per cubic foot.

64. *Uvaria triloba,* or paw paw; weighs 51 lbs. 6 oz. per cubic foot, and has a specific gravity of .359.

STONE.

13 cubic feet of marble weigh 1 ton.
13½ feet of granite weigh 1 ton.
The following table is from Dobson :—

WEIGHT OF TIMBER.

34	cubic	feet	of Mahogany	weigh	one ton.
39	"	"	Oak,	"	"
45	"	"	Ash,	"	"
51	"	"	Beech,	"	"
60	"	"	Elm,	"	"
65	"	"	Fir,	"	"

WAGES.

The price of labor in different portions of the United States, varies more than three hundred per cent.

WEIGHT OF EARTH.

13	cubic	feet	of chalk	weigh one ton.
17	"	"	clay	"
18	"	"	night soil	"
21¾	"	"	gravel	"
23½	"	"	sand	"

TILING.

A square of pantiling requires one bundle of laths and ¼ hundred of sixpenny nails.

A square of plain tiling requires one bundle of laths, one peck of tile pins, and three hods of mortar.

There are 12 pantile laths in a bundle; 30 bundles make a load.

MORTAR.

A cubic yard of mortar requires nine bushels of lime and one load of sand.

Lime and sand, and likewise cement and sand, lose one third of their bulk when made into mortar.

The proportion of mortar or cement, when made up, to the lime or cement and sand before made up, is as 2 to 3.

Lime or cement and sand to make mortar, require as much water as is equal to one third of their bulk.

A cubic yard of concrete requires 34 cubic feet of material; or if the gravel is to the lime as 0 to 1, a cubic yard of concrete will require one cubic yard of gravel and sand, and three bushels of lime.